NBSIR 87-3546

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Sponsored by:
Department of Agriculture
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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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INTRODUCTION

The increase of underground telephone cable installation by the telephone industry throughout the United States has created a demand for comprehensive and reliable information regarding the corrosion of shielding materials. In order to obtain such corrosion data on both currently accepted and experimental cable systems, the National Bureau of Standards (NBS) and the Rural Electrification Administration (REA) initiated an underground corrosion program. The program began in 1968 with the burial of thirty-one cable systems in selected soil environments. A paper summarizing the results for specimens buried for one year was given at the 18th International Wire and Cable Symposium (1). Since the first report many additional systems utilizing metals or plastic coated metals have been incorporated into the program. Other papers, summarizing the results obtained for these initial materials and the additional systems after burial for periods of up to six years, were presented at the Corrosion/74 (2) and Corrosion/76 Symposia (3). This paper (the seventh report) contains additional data for some of the systems included in the earlier reports. Table 1 describes the various cable systems included in this report.

SOILS AT THE TEST SITES

The chemical and physical properties of the soils at the test sites are given in Table 2. The chemical properties show that the soils differ widely with respect to their composition and their concentrations of soluble salts. The pH of the soils ranges from extreme acidity (4.0) to high alkalinity (8.8). The electrical resistivity of the soils ranges from 55 ohm-cm, which is approximately that of sea water, to 30,000 ohm-cm, indicating the absence of soluble salts. The physical conditions of the soils range from well aerated to poorly aerated.

These widely differing soil environments allow for a comprehensive soil corrosion program. The soils included are moderately corrosive (Sites B and D) to very corrosive (Sites A, C, E, and G) toward ferrous and other metals. The soils cover a wide range of soil properties found throughout the United States. Furthermore, it is possible to correlate corrosion data from these six soils with data previously obtained from 128 test sites in which the National Bureau of Standards has conducted extensive investigations on the underground corrosion of metals and alloys (3). Descriptions of the soils at the six test sites are as follows:

Sagemoor sandy loam (Site A) is a well-drained alkaline soil and is typical of soils found in vast areas of eastern Washington and Oregon. The site is located on the Yakima Indian Reservation near Toppenish, Washington. The soil is consistent in composition to a depth of at least seven feet and supports abundant growth of sage brush.

Hagerstown loam (Site B) is a well-drained soil representative of the majority of well-developed soils found in the eastern part of the United States. The site is located at the Loch Raven Reservoir of the

Baltimore City Water Department. The soil consists of a brown loam about one foot deep, underlain by a reddish-brown clay that extends five feet or more to underlying rock. Practically all of the materials that have been investigated in the extensive NBS soil corrosion tests since 1922 have been exposed at this site. Therefore, this site can serve as a reference site for the correlation of data obtained for specimens in the present program with data obtained from the earlier tests.

Clay soil (Site C) consists of a plastic gray clay to a depth of twelve inches. This is underlain by a poorly drained, very heavy plastic clay to which the specimens are exposed. The site is located in a large clay pit on level land at the U. S. Coast Guard Receiving Center at Cape May, New Jersey.

Lakewood sand (Site D) is a white, loose sand with some black streaks occurring in places and supports an abundant growth of beach grasses. The site is located in a well-drained rolling area on the property of the U.S. Coast Guard Electronic Engineering Station at Wildwood, New Jersey. The area is not subject to overflow from the ocean except under unusual flood conditions.

Coastal sand (Site E) is a typical white, coastal beach sand with a high content of black sand that occurs in streaks. This sand is similar to Lakewood sand in Site D except that at this site the sand is continuously saturated with salt water. The site is located on the Two-Mile Beach on the property of the U.S. Coast Guard Electronic Engineering Station, Wildwood, New Jersey.

Tidal marsh (Site G) is a soil typical of the poorly-drained marsh soils that are found along the Atlantic and Gulf coasts and is charged

with hydrogen sulfide. The site is located along a creek that empties into the Chesapeake Bay at Lexington Park, Maryland, on the property of the U.S. Naval Air Training Center.

TEST PROCEDURE

In order to expose the shield material to the environment and to simulate conditions which may occur in field installations of buried telephone cables, specimens were prepared as shown in Figure 1. Specimens used in this study were polyethylene jacketed cable lengths, approximately fourteen inches (35.6 cm) long, containing either metallic or plastic coated metallic shields. With a few exceptions, the shield was exposed by stripping the outer polyethylene protective jacket at two areas approximately four inches (10.2 cm) from one end of the cable length creating a window and a ring. The window was an exposed area along the length of the cable approximately two inches (5 cm) long x 0.5 inch (1.3 cm) wide, while the ring was an exposed area 0.5 inch (1.3 cm) wide around the circumference of the cable. In addition, some of the systems were electrically coupled to copper strips by mechanically bonding the strip to the shield at the ends of the cable with bonding harnesses (Figure 1). Coupling the shield to copper created a galvanic cell between the copper and the shield material. This was done to simulate field conditions in which dissimilar metal shields may be coupled either to existing cable systems having copper shields for shield continuity or to copper rods at grounding points. The ends of the specimens were sealed with a sealing compound and wrapped with vinyl tape to prevent entry of moisture at the end areas.

With a few exceptions, six specimens of each system were buried at each of the six soil sites. All specimens were buried at an approximate

depth of between three to four feet (0.9 to 1.2 m) below the ground line in trenches two feet (0.6 m) wide.

For the six previous NBS reports, a replicate specimen was withdrawn each year from each of the burial sites for cleaning and examination. For this report, a replicate specimen was withdrawn three years following the last previous recovery from each of the burial sites for cleaning and examination.

The areas examined on each specimen for corrosion were the exposed window, the exposed ring, the jacketed area, one-half inch around the exposed ring and exposed window and the remainder of the jacketed shield. After examining each area for corrosion, a numerical rating corresponding to the degree of corrosion was assigned to each area. The numerical rating system is listed in Table 3. When composite, clad or separate shielding materials were encountered, the outer, middle and inner shields at each area were rated individually. If the composite, clad or separate shielding contained two materials, the inner shield ratings were enclosed in parenthesis. If the above materials contained three materials, the middle shield ratings were enclosed in parenthesis.

RESULTS

The results obtained from the evaluation of cable specimens exposed for periods up to seven years in the various underground soil environments are summarized in Tables 4 through 9. At the time of this report, specimens from Site A had not been recovered since 1979. There had been no specimens removed from Site E, no specimens of Systems 73 through 94 removed from Site B and no specimens of Systems 89 through 94 removed from Sites C, D and G since the 1982 recovery. The results of

the specimens from Sites A and E, Systems 73 through 88 from Site B and Systems 89 through 94 from Sites B, C, D, and G were presented in the fourth, fifth, and sixth NBS reports, NBSIR 81-2243 (4), NBSIR 82-2509 (5) and NBSIR 85-2702 (6), respectively. Specimens of selected systems with varying degrees of corrosion are shown in Figures 2 through 48. The words "tacky" and "semi-tacky" are used to describe the filling compound used in the exposed specimens. Specimens with filling compounds were all tacky at the time of installation. As previously noted, areas of the shields were given numerical ratings to indicate the extent of degradation due to corrosion. A rating of ten indicates that the shield was unaffected by corrosion, while a rating of zero indicates severe corrosion sufficient to cause longitudinal electrical discontinuity (ELD) of the shield. When the shield exhibited ELD at all areas measured, it was considered to be destroyed. Examination showed that degradation of some specimens exposed for shorter periods of time was much more severe than that observed on similar specimens exposed for greater periods of time. This may be partially explained by the methods used in preparation of the specimens. If the cut through the outer jacket made to expose the window and ring was deep enough to penetrate the shield, it could allow corrosion of the inner shield materials. On the other hand, if the depth of cut was such that only the outer jacket was slit, then the integrity of the shield materials could be maintained.

Perhaps in future specimen preparations a device incorporating the shield and a probe in a medium voltage circuit could be used to detect cut-through of the coating to the metal shield underneath insuring an evaluation of the "coastal shield".

System 56. This system consisted of a 3-mil (0.1 mm) Type 430 stainless steel outer shield metallurgically bonded to a 3-mil (0.1 mm) 1100 aluminum alloy inner shield with a clear flooding compound on the core side.

Specimens of this system were exposed at Sites A, C, D, E and G only.

Delamination of the outer and inner shields was noted on nearly all of the specimens examined.

There was no degradation of either the outer or inner shields of specimens exposed for six years at Site A and five years at Site D; nor was there any degradation of the outer shield on specimens buried for up to six years at Site C and four years at Site E. The outer shield was ELD or near ELD at the window and ring areas on specimens exposed for four and six years at Site G. The inner shields were perforated due to localized corrosion after burial for four and six years at Site C and three, four, and six years at Site G. The inner shield was at or near ELD on specimens exposed from two to six years at Site G.

The filling compound was still tacky except where corrosion was observed.

System 57. This system is the same as System 56 except that the system was coupled to copper.

Specimens of this system were exposed at Sites A, C, D, E, and G only.

As noted for System 56, there was delamination of the outer and inner shields on nearly all specimens examined.

In general there was no degradation of the outer shield on specimens buried for up to six years at Sites A, C, D, and E. Localized

corrosion pitting was noted on the outer shield of one specimen exposed for one year at Site A. The outer shields were perforated due to corrosion at window or ring areas on specimens buried at Site C for five and six years.

There was no degradation of the inner shield on specimens buried from two to six years at Site A and one year at Site C. For the specimens buried at Site C for four to six years, the inner shield was ELD or near ELD at jacketed and exposed areas. The inner shield of specimens buried at Site D for three and five years and at Site E for two and three years were ELD at the window, while all areas of the inner shield exposed at Site E for six years were ELD. Similarly, the inner shield of specimens exposed at Site G was ELD at all examined areas, while only the window and ring areas were ELD on the outer shield for the same exposed time.

The filling compound was tacky except at areas where the shields were corroded.

<u>System 58.</u> This system consisted of a 3-mil (0.1 mm) Type 304 stainless steel outer shield with a 4-mil (0.1 mm) vapor deposited aluminum alloy coating on the inner shield.

Specimens of this system were exposed at Sites A, C, E, and G only.

The outer shield was unaffected by corrosion at Sites A and E for up to six years. No corrosion or only superficial corrosion was noted on specimens from Site C for up to three years of exposure. The outer shield buried for six years at Site C was noted as having superficial corrosion at all areas examined, while all areas examined on the inner shield were ELD or near ELD. Corrosion in varying degrees was noted on the outer shield after being buried up to six years at Site G. However,

the inner shield at the same site was ELD at all areas examined. The specimen at Site E was not installed for the six year exposure because of a lack of prepared specimens.

System 59. This system is the same as System 58 except that the system was coupled to copper.

Specimens of this system were exposed at Sites A, C, E, and G only.

With few exceptions, corrosion was superficial or nonexistent on the outer shield exposed up to five years at Sites A and C, and six years at Site E. Specimens buried for five and six years at Site G were perforated due to corrosion on the outer shield at all areas examined, while the inner shield was ELD for specimens exposed for two to six years. All areas of the inner shield were also ELD for specimens buried for two to six years at Site E.

System 60. This system consisted of a 3-mil (0.1 mm) Type 304 stainless steel shield with a 2-mil (0.05 mm) vapor deposited aluminum coating on the outer and core sides of the shield.

Specimens of this system were buried at Sites A, C, E, and G only.

There was no apparent corrosion of the stainless steel on any of the specimens buried for up to five years at these sites. With very few exceptions, the stainless steel shield was unaffected by corrosion at all areas examined for specimens buried for up to six years at Sites A, C, and E. The stainless steel shield for specimens from the six year exposure at Site G was perforated at and adjacent to the window area as well as at the jacketed areas examined. The vapor deposited aluminum coated outer shield was near ELD at all areas except for the area adjacent to the ring on the specimen buried up to five years at Site A, while the vapor deposited aluminum inner shield showed slight corrosion

at all areas. Both inner and outer vapor deposited aluminum shields of specimens buried for five and six years at Site C were at or near ELD, while companion specimens at Site G for two through six years were ELD at all areas examined. The outer aluminum shield at and adjacent to the window and ring areas of specimens buried for four years at Site E were ELD. The inner aluminum shield at the jacketed areas was ELD for the same exposure time. The specimen at Site E was not installed for the six year exposure because of a lack of prepared specimens.

System 61. This system is the same as System 60 except that the system was coupled to copper.

Specimens of this system were buried at Sites A, C, E, and G only.

Coupling this system to copper accelerated corrosion on the inner and outer vapor deposited aluminum coating at all four sites. In general, the stainless steel shield specimens exposed at Sites A and E for up to five years were unaffected by corrosion. However, the stainless steel shield specimens exposed at Site G for up to six years were perforated due to corrosion at nearly all areas examined. With few exceptions, the stainless steel shields exposed at Site C for two, four, and six years were unaffected by corrosion. Perforation due to severe corrosion on the inner aluminum shields exposed at Site A was observed, while ELD or near ELD of the outer aluminum shield of specimens buried up to five years was evident. Specimens exposed for two through six years at Sites C, E, and G were ELD at all areas on the inner and outer aluminum shield.

__System 62.__ This system consisted of a 50-pair, 22-gauge air core cable having an 8-mil (0.2 mm) aluminum shield with a copolymer coating on both sides of the shield. There was no window or ring on specimens of this system. The conductors were removed from the cable leaving a hollow shell with no taped ends.

The performance of this system showed no corrosion after exposure for five years at Sites A and C and for four years at Site B. Specimens exposed for up to six years at Sites D and E indicated no corrosion except for the specimens exposed for four years. Perforation due to localized corrosion pitting was noted for specimens exposed at Site G for two and four years, while companion specimens exposed for three and five years were unaffected by corrosion. Specimens from Sites C and G showed minor degradation after exposure for six years.

__System 63.__ This system consisted of a 16-pair, 22-gauge cable having an 8-mil (0.2 mm) uncorrugated aluminum alloy shield which was bonded on both sides to a polyolefin film. The shield was bonded to the jacket. There was no window or ring on specimens of this system. The conductors were removed from the cable leaving a hollow shell.

No corrosion was observed on specimens buried for five years at Site A and for six years at Sites B, C, D, and E. The shields of specimens buried for two, four, and five years at Site G were perforated due to corrosion, while companion specimens exposed for one, three, and six years were unaffected by corrosion. Slight dissipation of the shield was noted at the sheared ends of the specimens.

System 64. This system consisted of a 25-pair, 18-gauge cable having an 8-mil (0.2 mm) uncorrugated aluminum alloy shield which was coated on both sides with a 2-mil (0.05 mm) polyolefin film. The shield was bonded to the jacket. There was no window or ring on specimens of this system. The conductors were removed from the cable leaving a hollow shell.

Specimens exposed for four years at Site B, five years at Site A, and six years at Sites D and E were unaffected by corrosion. Only four specimens were buried at Site B due to a lack of sufficient specimens to allow for a five and six year exposure. Pitting which resulted in corrosion perforation of the shield was observed on the specimens buried for four years at Site C and specimens exposed for four, five and six years at Site G. The shield of the specimen from Site C buried for six years showed minor corrosion degradation. Slight metal dissipation at the exposed sheared ends of the specimens was observed at all sites.

System 65. This system consisted of a 25-pair, 24-gauge cable having an 8-mil (0.20 mm) uncorrugated aluminum alloy shield which was bonded on both sides with a polyolefin film. The shield was bonded to the jacket. There was no window or ring on specimens of this system. The conductors were removed from the cable leaving a hollow shell.

There was no apparent corrosion on specimens of this system after exposure for five years at Site A and for six years at Sites B, C, D, E, and G.

System 66. This system is the same as System 65 except that the shield was coupled to copper.

Specimens of this system were exposed at Sites A, B, C, D, and E only.

These specimens were unaffected by corrosion after exposure for up to five years at Site A and for up to six years at Sites B, C, D, and E.

System 67. This system consisted of 4-mil (0.1 mm) aluminum foil 3 3/4 in. x 8 in. (9.5 cm x 20.3 cm) coated on both sides with a 6-mil (0.15 mm) ethylene acrylic acid copolymer.

Specimens of this system were exposed at Sites A, B, C, and D only.

There was no apparent degradation of specimens of this system after exposure for two years at Site A and for five years at Sites B, C, and D. Specimens buried for two years at Sites B and D and for three and five years at Site C were not recovered.

System 68. This system consisted of 4-mil (0.1 mm) aluminum foil 3 3/4 in. x 8 in. (9.5 cm x 20.3 cm) coated on both sides with a 6-mil (0.15 mm) polyester film.

These specimens were exposed at Sites A, B, C, and D only.

Specimens of this system were unaffected by corrosion after exposure for three years at Site A, four years at Site C, and five years at Sites B and D. The specimen buried for five years at Site C was not recovered.

System 69. This system consisted of 4-mil (0.1 mm) aluminum foil 1 1/2 in. x 12 in. (3.8 cm x 30.4 cm) coated on both sides with a 5.5 mil (0.14 mm) polyester film.

These specimens were exposed at Sites A, B, C, and D only.

Corrosion of specimens of this system was nil after exposure for up to three years at Site A, four years at Site D, and five years at Sites B and C. Specimens exposed for one, three, and five years at Site D and for three years at Sites B and C were not recovered.

System 70. Specimens of this system (Table 1) were exposed at Sites A, B, C, and D only.

Corrosion was nil for specimens buried for up to two years at Site A and up to five years at Sites B, C, and D. Severe corrosion was observed for the specimen exposed for three years at Site A . Where more than 25 percent of the metal shield was dissipated due to corrosion. There was no window or ring on specimens of this system.

Systems 71 and 72 were buried plant housings and are not included in this report.

System 73. The inner and outer shields of specimens of this system (Table 1) exposed for one year at all sites were not severely unaffected by corrosion. Degradation of the outer black plate steel shield was severe at the window and ring areas on the specimen buried at Site B for up to three years. The outer shield was near ELD at the window and ring areas for specimens buried for three and four years at Site B. The outer shield of the specimens exposed at Site A for two years and at Site C for two and three years was severely corroded at the window and ring areas, while the specimen from Site D showed only minor corrosion. The same areas of the specimens exposed for four and seven years at Site C were ELD. The window and ring area on the outer shield at Site D were near ELD on the specimens exposed for seven years. Perforation due to corrosion at the window areas of the outer shield of specimens exposed for two years at Site E was noted as was the severe corrosion at the window and ring areas exposed for four years. The outer shield except for jacketed areas exposed for three and four years at Site G was at or near ELD while all areas examined on the specimen at Site G after seven years exposure indicated the outer shield was ELD. The inner aluminum

alloy shield showed little effect by corrosion except at Site G where ELD, or near ELD, was observed at or adjacent to the window and ring areas on specimens exposed for three, four and seven years, while the inner aluminum alloy shield at Site C was ELD at all areas on the specimen exposed for seven years.

System 74. This system was the same as System 73 except that the shields were coupled to copper.

Coupling specimens of this system to copper accelerated corrosion of the shields, at all areas examined. With few exceptions corrosion on the inner shields of specimens buried up to three years at all sites was nil or superficial. Specimens at Site B were ELD, or near ELD, for the first four years of exposure on the outer shield at both the window and ring areas, while the regions adjacent to the window and ring areas were severely corroded. Severe degradation of the outer shield was noted at the window and ring areas exposed for up to four years at Site D and up to three years at Site E, while the outer shield of the specimens exposed at Site D for seven years and at Site E for four years were ELD at the window and ring areas. After four years of exposure the inner shield of the specimen buried at Site C was ELD at all areas examined as was the outer shield except at the jacketed areas, while the specimen after seven years of exposure at Site C was ELD at all areas examined and was considered destroyed. The inner shield of the specimen exposed at Site D for seven years indicated slight corrosion at all examined areas. Of the specimens buried at Site G all areas examined on the inner shield were ELD after two and three years of exposure. The outer shield at the window area was ELD on specimens exposed at Site G for one, two, and three years, while the ring and adjacent area were ELD on

specimens buried for two and three years. The specimens exposed for four and seven years at Site G were ELD at all areas examined and were considered destroyed.

The filling compound was still tacky except at corroded areas.

System 75. The inner aluminum alloy shield on specimens of this system (Table 1) exposed for up to four years at Sites B and E and for seven years at Sites C, D and G were unaffected by corrosion. The outer steel shield on specimens buried at Sites C, E, and G for one year, Sites A and B for up to two years, and Site D for up to four years was also unaffected by corrosion. Corrosion was superficial or nil on specimens buried at Site E for up to four years.

With one exception, corrosion at all areas examined on both shields was nil on specimens buried for one to three years at Site C. The outer shield showed slight corrosion at all areas examined after two years of exposure at the same site, while only the window and ring areas showed slight corrosion after four and seven years of exposure. The specimen exposed for seven years at Site D indicated slight corrosion of the outer shield at only the window and ring areas. At Site G the window area was near ELD for the specimens buried for two and four years and near ELD at and adjacent to the ring area after three years exposure. The specimen buried for seven years at Site G was ELD at all examined areas.

The filling compound was still tacky except at corroded areas.

System 76. Same as System 75 except that the shields were coupled to copper.

Coupling the shields to copper accelerated the corrosion of the outer shield in the soils in which the specimens were exposed for up to

four years at Sites B and E and seven years at Sites C, D, and G. No degradation was observed on the inner aluminum alloy shield of the specimens buried for up to four years at Sites B, E, and G and up to seven years at Site D. The inner shield of the specimen exposed up to four years at Site C indicated corrosion at the ring area as a result of perforations while specimens exposed for seven years at Site C indicated the inner shield was ELD at all areas. With one exception the outer steel shield was corroded to varying degrees at exposed areas on all specimens exposed for up to four years. Corrosion at these areas was most severe on specimens buried at Sites C, E, and G. After seven years exposure at Site C, the outer shield of the specimen was observed to be ELD at or adjacent to the window and ring areas while the specimen buried at Site G for the same length of time was ELD. The unjacketed area was unaffected. The outer shield of the specimen exposed up to seven years at Site D indicated moderate corrosion at the window and ring areas and the area adjacent to the ring.

The filling compound was still tacky except at corroded areas.

System 77. The aluminum alloy inner shield on specimens of this system (Table 1) were unaffected by corrosion after exposure for up to two years at Site A, for up to four years at Sites B and C and for up to seven years at Site D. One specimen buried for four years at Site E and two specimens buried for three and four years, respectively at Site G exhibited some corrosion. After seven years exposure at Site C, the aluminum alloy inner shield was considered to be ELD. There was no degradation of the outer steel shield of specimens buried for one year at Sites A, B, and D. After exposure for three years, corrosion of the outer shield was superficial or nil at jacketed areas of all specimens

except for those exposed at Sites B and C. Corrosion of the outer shield was observed at the window and ring areas of all specimens buried for two and three years in all soils. The outer shield of the specimens exposed at Site D for four and seven years indicated mild to severe corrosion at the window and ring areas. The specimens exposed for four years at Sites B, C and E were at, or near ELD, on the outer shield at or adjacent to the window and ring areas. The outer shield at, or adjacent to, the window and ring areas of the specimens exposed for up to seven years at Site C was considered to be ELD. Corrosion perforations due to localized pitting was noted at window and ring areas on specimens buried at Sites A and D for two years and on the outer shield for specimens buried at Sites B and C for up to three years. The specimens exposed at Site G for two, three, and four years were ELD on the outer shield at and adjacent to the window and ring areas and ELD on the inner shield at all areas examined except the area adjacent to the window after exposures for four years. The specimen at Site G exposed for seven years was considered destroyed.

The filling compound was still tacky except at corroded areas.

System 78. Same as System 77 except that the shields were coupled to copper.

Coupling the shields to copper accelerated corrosion of the outer shield in all of the soils and of the inner shield at Sites C, E, and G. The inner shields of specimens buried for four years at Sites B and D were unaffected by corrosion. The inner shield of the specimen buried for seven years at Site D was slightly corroded at the window and ring areas and the area adjacent to the ring. Corrosion of the inner shield on specimens buried at Sites C and G occurred at and adjacent to the

window and ring areas. For specimens buried at Site G for three years and at Site C for seven years, the inner shield was ELD or near ELD at window and ring areas and severely corroded at jacketed areas. The specimens exposed at Site G for four and seven years were ELD at all areas examined and were considered destroyed. In general, severe corrosion was observed on the outer shield at the window and ring areas on all specimens of this sytem. For the specimens buried for two and three years at Sites B, C, and G, the outer shield was at or near ELD at the window and ring areas. For the specimens buried for four years at Sites B and C, the outer shields were either ELD or near ELD in the areas of the window and ring. The outer shield of the specimen exposed for up to seven years at Site C was ELD for all areas examined and was considered destroyed. Corrosion of the outer shield was severe at the window and ring areas on specimens of this system buried for two years at Site A, seven years at Site D, and four years at Site E.

The filling compound was still tacky except at corroded areas.

System 79. Except for the specimens of this system (Table 1) buried at Site G and one specimen at Site C, there was no degradation of the inner aluminum alloy shield on any of the specimens buried up to four years at Sites B and E and seven years at Site D. Severe corrosion was noted on the inner shield at the window and ring areas on specimens exposed for up to two years at Site G and at or near ELD at all areas examined on the specimens buried for three, four and seven years at Site G and seven years at Site C. In general, corrosion of the outer steel shield occurred at or adjacent to the window and ring areas. The specimens at Sites B and C for four years and Site D for seven years were severely corroded at the ring areas. The outer shield of the

specimen buried for up to seven years at Site C was at or near ELD for all areas examined. Perforation due to corrosion at the jacketed and adjacent window areas was observed after exposure for one year at Site E. At the same site, the window and ring areas of the outer steel shield were perforated due to corrosion for specimens exposed for two and three years. The specimens buried for up to four and seven years at Site G were at or near ELD at the window and ring areas. The specimen exposed for four years at Site E was not recovered.

The filling compounds were still tacky at all uncorroded areas, while corroded areas were noted as dry.

System 80. Same as System 79 except that the shields were coupled to copper.

With a few exceptions, there was little or no corrosion on either shield at jacketed areas of specimens buried at Sites A and C for two years and Sites D and E for three years. The inner aluminum alloy shield was perforated due to corrosion at window and ring areas on specimens buried for three and four years at Site B and for two and three years at Site D. All areas examined on the inner shield were ELD for specimens exposed for four and seven years at Site C. Specimens buried for three, four, and seven years at Site D were at or near ELD at the window and ring areas, while only the four year exposure was ELD at the ring area at Site E. Specimens exposed for three and four years at Sites B, C, G, and four and seven years at Site D were ELD at the window and ring area on the outer steel shield and were ELD on both shields of specimens exposed at Sites C and G for three, four and seven years. All areas examined on the inner and outer shields of specimens buried at Site G for two, three, four, and seven years were ELD and were considered destroyed.

The filling compounds were still tacky at all uncorroded areas, while corroded areas were noted as dry.

System 81. There was no corrosion of the inner aluminum alloy shield for specimens of this system (Table 1) after exposure for one and two years at Sites A and G, for up to four years at Sites B, C, and E and for up to seven years at Site D. The inner shield of the specimen exposed for up to seven years at Site C was severely corroded at, and adjacent to, the window and ring areas. Corrosion of the steel outer shield in varying degrees was noted at window and ring areas in specimens exposed up to four years at Sites B, C, D, and E. The outer shield exposed for up to seven years at Sites C and D were either severely corroded or near ELD at the window and ring areas. The inner and outer shields at the window and ring areas of the specimens were at or near ELD after the third and fourth year of exposure at Site G. However, only the inner shield was ELD at the adjacent ring area after the third year of exposure. The specimen buried at Site G for seven years indicated that both shields were ELD at all areas examined thus classifying the specimen as destroyed.

System 82. Same as System 81 except that the shields were coupled to copper.

Coupling specimens of this system to copper accelerated corrosion of the outer steel shield at window and ring areas in all of the soils. The inner and outer shields at jacketed areas exhibited little or no corrosion after exposure for up to two years at Sites A and B and for up to three years at Sites D and E. Corrosion was noted at and adjacent to the window and ring areas of the specimen exposed for four years at Site E. Severe corrosion was observed on the outer steel shield at the

window and ring areas of specimens buried for two years at Site A and for up to four years at Sites D and E. The specimen exposed for seven years at Site D indicated that the outer shield was at or near ELD condition at all examined areas. The inner shield of the same specimen was at or near ELD conditions at all examined areas except for the area under the jacket. The outer shield at the window and ring areas was severely corroded after exposure of one year at Site B as were the adjacent window and ring areas of the outer shield after exposure for three and four years. The specimen exposed for four years at Site C was ELD at all areas examined on the outer shield except at the unjacketed areas, whereas, the specimen exposed for seven years was ELD at all areas examined. Specimens buried for two and three years at Site B and one year at Site G were ELD at the window and ring areas, while specimens exposed at Site G for two, three, four and seven years were ELD at all areas examined and were considered destroyed.

The filling compound was semi-tacky to dry for all specimens.

System 83. With few exceptions specimens of this system (Table 1) were unaffected by corrosion. Specimens exposed at Site C were perforated due to corrosion on the outer steel shield at the window and ring areas for specimens exposed up to two years and severely corroded at the same areas after three years while after seven years these same areas were ELD. The inner shield on the specimen exposed for seven years at Site C was ELD at all examined areas. The inner aluminum alloy shield of the specimen exposed for seven years at Site D was unaffected by corrosion while the outer steel shield of the same specimen indicated slight corrosion at all areas except for the area adjacent to the ring. The aluminum alloy inner shield of specimens exposed for two

years at Site G showed slight corrosion at the adjacent window areas, while severe corrosion was observed at the window and ring areas of specimens buried at the same site for the same amount of time. The window and the area adjacent to the window were ELD on the specimen buried at Site G for four years with all examined areas being ELD on the specimen exposed for seven years at the same site. Perforation was noted at the window and ring areas of the outer shield for specimens exposed at Site G for two years and at the region adjacent to the ring area of specimens exposed for up to three years. The window area of the outer shield was near ELD on the specimens buried for three and four years at Site G, as was the region adjacent to the window area of the specimen buried for four years. For the specimen exposed at Site G for seven years, the window area was considered ELD while the ring area was considered near the ELD condition. The specimen exposed at Site C for four years was not recovered.

The filling compound was semi-tacky to dry for all specimens.

System 84. Same as System 83 except that the shields were coupled to copper.

Coupling specimens of this system to copper accelerated the corrosion of the outer corrugated steel shield of specimens buried in five of the six soils. The specimen at Site A was unaffected by corrosion after an exposure of two years. Specimens from Sites C and E showed varying degrees of corrosion on the inner shield after four years of exposure. After seven years of exposure at Site C the inner shield was ELD at all examined areas. The inner shield of the specimens buried at Site D for seven years was ELD at only the window area and the area adjacent the window. Varying degrees of corrosion were noted at the

window and ring areas on the outer shield of specimens buried at all sites for up to four years. Perforation due to corrosion was observed at the window and ring areas for specimens exposed at Sites B, C, and E for up to four years, and at Site D for two, three, and four years. After seven years of exposure at Site C the outer shield was ELD at all areas examined, while the specimen exposed at Site D for seven years indicated that the outer shield was at or near ELD at only the window and ring areas. The outer shield of the specimen exposed for two years at Site G was ELD at the window and ring areas. However, ELD was observed on both shields at the same areas of specimens exposed at Site G for three years. All inner shield areas except the region adjacent to the window area were ELD after exposure for three years at Site G. After four and seven years exposure at Site G, the inner shield was ELD at all areas. After four years of exposure at Site G, all areas of the specimens were ELD except for the jacketed areas on the outer shield. After seven years of exposure at the same site, only the unjacketed window area was ELD with all other areas showing signs of very severe corrosion.

The filling compounds were semi-tacky to dry for all specimens.

System 85. With few exceptions specimens of this system (Table 1) were noted as having superficial or negligible degradation on the inner aluminum alloy shield exposed for up to three years at Sites C and E and up to four years at Sites B and D. Varying degrees of corrosion were noted at all areas examined on the inner shield of the specimens exposed for four years at Sites C and E with the most severe corrosion occurring at and adjacent to the ring areas at Site C. The inner shield of the specimen exposed at Site C for seven years was ELD at all areas while

the inner shield of the specimen exposed at Site D for seven years showed superficial or slight corrosion at all areas examined. The inner shield at the ring area was near ELD on the specimen buried at Site G for one year. Companion specimens buried for two, three, four, and seven years at the same site were severely corroded at all areas examined and were considered destroyed. The corrugated steel outer shield was unaffected by corrosion on specimens buried at Site A for two years. Perforation due to severe corrosion was noted at the window and ring areas on the outer shields of the specimens exposed for three and four years at Sites B, C and E, and for three, four and seven years at Site D. The outer shield of the specimen at Site C was at, or near, ELD at the window and ring areas exposed for four years while after seven years of exposure at the same site the outer shield was ELD at all areas and was considered destroyed. Slight degradation on the inner shield at, and adjacent to, the window area of the specimen exposed at Site C was observed after three years of exposure. The specimen exposed at Site E for three years was not recovered.

The filling compound was semi-tacky to dry for all specimens.

System 86. Same as System 85 except that the shields were coupled to copper.

Coupling specimens of this system to copper accelerated corrosion of the shields, particularly at the unjacketed areas. The inner aluminum alloy shields of the specimens buried for two, four, and seven years at Site C were ELD at all areas examined. The specimen exposed for three years at the same site was ELD at and adjacent to window and ring areas. Severe corrosion of both shields was noted on specimens buried up to seven years at Site G. The inner shield on the specimen

exposed for one year at Site G was perforated due to corrosion at all areas examined, while corrosion on the outer steel shield at jacketed areas was negligible. Specimens buried at the same site were ELD on the outer shield at the window and ring areas after one year exposure. Both shields were ELD at all areas examined for specimens exposed at Site G for two, three, four and seven years and were considered destroyed. With few exceptions for the specimens buried in the other four sites for four years, both shields were perforated to severely corroded at all areas examined. For the specimen buried at Site D for seven years, both shields were ELD at all areas examined and considered destroyed.

The filling compound was semi-tacky to dry for all specimens.

System 87. There was no degradation of the corrugated aluminum alloy inner shield on specimens of this system (Table 1) buried up to one year at Site G, two years at Site A, four years at Sites B, C, and E, and seven years at Site D. The inner shield of the specimen exposed for two years at Site G was perforated due to corrosion at all areas examined, while the companion specimens exposed for three, four and seven years were ELD at all areas on both the inner and outer shield and were considered destroyed. Perforations due to localized corrosion pitting at the window and ring areas on the steel outer shield was noted for specimens exposed at Site A for one and two years and at Site D for two, three, and four years. The steel outer shield of the specimen buried at Site D for seven years was near ELD at the window and ring areas. Companion specimens at Sites B, C, and E buried up to four years were perforated or severely corroded at or adjacent to window and ring areas. Both shields on the specimen buried at Site C for seven years were ELD at all areas examined.

The filling compound was semi-tacky to dry for all specimens.

System 88. Same as System 87 except that the shields were coupled to copper.

Coupling the specimens of this system to copper accelerated the corrosion of the black plate steel outer shield at the window and ring areas after exposures of up to two years at Site A, four years at Sites B, C, and E, and seven years at Site D. The window and ring areas of the black plate steel outer shield were ELD after one year of exposure at Site G. The outer shields at exposed areas ranged from mild to very severe corrosion for specimens buried at the six sites. Corrosion of the corrugated aluminum alloy inner shield was negligible at all areas examined for up to one year at Site C, two years at Site A, three years at Site D, and four years at Sites B and E. The inner shield of the specimen buried at Site C for two years was at or near ELD at the window and adjacent to the window area. After three years of burial at Site C, the inner shield was ELD at all areas examined. The inner shield of the specimen exposed at Site D for four years was noted to be severely corroded and perforated at the window as a result of localized pitting. The specimen buried at Site D for seven years exhibited severe corrosion of the inner shield at all areas examined with the most severe corrosion occurring at the ring area. Both shields of the specimens exposed at Site G for two, three, four and seven years and at Site C for four and seven years were ELD at all areas rated, and were considered destroyed.

The filling compound was semi-tacky to dry on all specimens.

System 89. This system consisted of a 100-pair, 22-gauge semi-conducting cable having a 5-mil (0.1 mm) corrugated copper alloy shield

and a low density polyethylene jacket.

With one exception, corrosion on the specimens of this system was nonexistent in all of the soils after exposure for three years. Perforation due to corrosion was noted at or adjacent to the window and ring areas of the specimen exposed for three years at Site G.

System 90. Same as System 89 except that the shield was coupled to copper.

Coupling specimens of this system to copper had little or no effect on the corrosion behavior of the copper alloy shield.

System 91. This system consisted of a 3-mil (0.1 mm) corrugated 1006 low carbon steel outer shield bonded to a 3-mil (0.1 mm) 4022 aluminum alloy inner shield.

Corrosion of either shield at the jacketed areas was not appreciable for specimens buried for one year at Site D or two years at Site B. Severe corrosion was observed on the outer shield at the window and ring areas of specimens exposed for up to two years at Sites C and E. The specimens were ELD or near ELD at the window and ring areas on both shields exposed for two and three years at Sites B and D. The inner and outer shields were at or near ELD at the window and ring areas on specimens exposed for one and two years at Site E. The specimen at Site A was ELD at all areas examined after one year of exposure and was considered destroyed. The same was observed for the specimen at Site G exposed for one, two, and three years, and for three years at Sites C and E. All three specimens were considered destroyed at these sites.

System 92. Same as System 91 except that the shields were coupled to copper.

Specimens of this system were exposed at Sites A, B, and G only.

Coupling the specimens of this system to copper accelerated corrosion of both shields. Corrosion of varying degrees was noted on the inner aluminum alloy shield for specimens buried at Site B for two years with ELD noted at the window and ring area after three years of exposure. The outer shield was at or near ELD at the window and ring areas for specimens exposed at Site B for two and three years. The shields of specimens were ELD at all areas and were considered destroyed after burial for one year in all three soils and for up to three years at Site G.

System 93. This system consisted of a 3-mil (0.1 mm) corrugated 1006 low carbon steel inner shield bonded to a 3-mil (0.1 mm) 4022 aluminum alloy outer shield.

Specimens of this system were exposed at Sites A, B, C, D, and E only.

With one exception there was no appreciable degradation of the outer aluminum alloy shield after exposure for one year at these sites. The outer shield of the specimen exposed for one year at Site A was perforated at all areas examined, while the inner shield was ELD at all areas except under the jacket. Corrosion of the inner and outer shield varied from superficial to moderate at all areas examined after burial for up to two years at Sites B, C, D, and E. Perforation due to corrosion was noted both at or adjacent to the window and ring areas on the specimens exposed for three years at Sites B, D, and E. The specimen exposed at Site C for three years was not recovered.

System 94. Same as System 93 except that the shields were coupled to copper. Specimens of this system were exposed at Sites A and B only.

Coupling the specimens of this system to copper accelerated corrosion of both shields. Both the inner and outer shields of specimens exposed for one year at Site A and up to three years at Site B were ELD at all areas examined and were considered destroyed.

System 95. This system was a coaxial cable consisting of a 25-mil (0.6 mm) uncorrugated seamless aluminum alloy outer shield and a 112-mil (2.8 mm) solid copper alloy center conductor with a high density polyethylene jacket.

Specimens of this system were exposed at Sites B, C, D, E, and G only.

For specimens buried up to one year at Site C, up to two years at Site E, and up to five years at Sites B and D, the evaluation indicated that corrosion of the aluminum alloy outer shield was nonexistent or superficial. For the specimen buried at Site C for four years, slight corrosion of the outer shield was noted at all areas examined. The specimen buried at Site G was ELD at the window and ring areas and experienced severe corrosion at the area adjacent to the window for the first year of exposure, while the specimen exposed for the second year was perforated due to corrosion at the window and ring areas. The specimen at Site G after five years of exposure was ELD at all areas and was considered destroyed.

System 96. Same as System 95 except that the shields were coupled to copper.

Specimens of this system were exposed at Sites B, C, D, E, and G only.

Coupling specimens of this system to copper accelerated corrosion of the shields buried for one year in all soils. In general, there was

little or no degradation of the specimens buried for up to five years at Site B. The specimen exposed at Site C for one year was ELD at the window, ring, and region adjacent to the ring area, while the specimen exposed at the same site for four years was ELD for all areas examined and was considered destroyed. Perforation due to corrosion was noted on the specimen at or adjacent to the window and ring areas exposed for up to five years at Site D and two years at Site E. The unjacketed areas on specimens buried at Sites D and E were perforated due to corrosion pitting. The specimens exposed for up to five years at Site G were ELD at all areas examined and were considered destroyed. The specimen from Site D was exposed without a window for the first year of exposure.

System 97. Specimens of this system (Table 1) were exposed at Sites B, C, D, E, and G only.

There was little or no corrosion on the specimens exposed at Site C for up to four years. Specimens of this system were unaffected by corrosion during their first two years of exposure at Site E and the first five years of exposure at Sites B and D. The shield of the specimen from Site G was severely corroded at the ring area and near ELD at the window area exposed for one year, while ELD was observed at the ring area of the companion specimen buried for two years. The specimen exposed after five years at Site G indicated that the window and ring areas were ELD with very severe corrosion occurring at the area beneath the jacket.

The filling compounds were dry.

System 98. Same as System 97 except that the shields were coupled to copper.

Specimens of this system were exposed at Sites B, C, D, E, and G

Specimens of this system were exposed at Sites B, C, D, E, and G only.

Coupling the specimens of this system to copper accelerated the corrosion of the aluminum alloy shield. For the specimens buried at Sites B and D for up to five years, slight corrosion was noted at the window and ring areas with severe corrosion occurring at the area adjacent to the ring on the specimen buried at Site B for five years. The specimen buried at Site C for one year was ELD at the window and ring areas, while the specimen buried at the same site for four years was ELD at and adjacent to the window and ring areas. The specimen exposed at Site E was perforated due to localized corrosion pitting at the window and ring areas after one year of exposure, while the same areas were ELD after two years of exposure. After burial for one year at Site G, the shield of the specimen was near ELD at the area adjacent to the window, while the window, ring, and regions adjacent to the ring areas were ELD. The specimens buried for two and five years at the same site were ELD at all areas examined and were considered destroyed.

The filling compound was still tacky at all areas.

System 99. Specimens of this system (Table 1) were exposed at Sites B, C, D, E, and G only.

Corrosion was nil or superficial on both shields of the specimens buried for up to two years at Site E, four years at Site C, five years at Site B, and one year at Site D. Corrosion of the inner shield was nil on the specimens buried for up to two years at Site G and up to five years at Site D. The tin-free steel outer shield of the specimens buried for up to five years at Site D was perforated at the window and ring areas as a result of localized corrosion pitting. At Site G, the

developed severe corrosion at the window area and perforation due to localized pitting corrosion at the ring area. The companion specimen showed severe corrosion at and adjacent to the window and ring areas after two years exposure. For the specimen exposed for five years at Site G, both shields were severely corroded at all areas due to perforations which resulted from localized corrosion pitting. In addition, the outer steel shield window area was ELD.

The filling compound was still tacky.

System 100. Same as System 99 except that the shields were coupled to copper.

Coupling the specimens of this system to copper accelerated the corrosion of the tin-free steel outer shield exposed for up to two years at Site E, four years at Site C, and five years at Sites B and D, while the only inner shields to be severely corroded were from specimens exposed for four years at Site C and two years at Site G. After exposure for four years at Site C, five years at Sites B and D and two years at Site G, the window and ring areas were severely corroded due to perforations which resulted from localized pitting corrosion. The specimen exposed for two years at Site B was perforated due to corrosion at the area adjacent to the window, while the specimen exposed for two years at Site D was corroded at the area adjacent to the ring. The sample exposed for five years at Site G was ELD at all areas examined and was considered destroyed.

The filling compound was still tacky at all areas.

System 101. Specimens of this system (Table 1) were exposed at Sites B, C, D, E, and G.

There was no degradation on the uncorrugated aluminum alloy inner shield on the specimens buried up to two years at Sites E and G, four years at Site C, and five years at Sites B and D. The specimen exposed at Site C for one year was perforated due to corrosion on the outer shield at the window area and slightly pitted at the ring area. A companion specimen also buried at Site C after four years showed slight pitting at and adjacent to the window and ring areas on the outer shield. The tin-plate steel outer shield of the specimen exposed at Site B for one year was noted to have slight rust stains at the jacketed and unjacketed seamed areas, while the specimen exposed for two years at the same site was observed to have perforations at the ring area. The outer shield of the specimen exposed for five years at Site B indicated only slight pitting at the window area. For specimens buried for two years at Sites D and E, perforations due to corrosion were observed at the window and ring areas of the outer shield, while the specimen exposed for five years at Site D ranged from superficial to slight corrosion at all areas examined on the outer shield. The outer shield of the specimen buried at Site G for one year was perforated by corrosion at all areas examined. Corrosion was severe on the companion specimens from the same site at all areas examined with ELD occurring at and adjacent to the window areas exposed for two and five years.

The filling compound was semi-tacky except at corroded areas where it was dry.

System 102. Same as System 101 except that the shields were coupled to copper.

Specimens of this system were exposed at Sites B, C, D, E, and G only.

Coupling specimens of this system to copper accelerated corrosion of the corrugated tin-plate steel outer shield. All areas examined on the aluminum alloy inner shield were unaffected by corrosion after exposure for up to two years at Sites E and G, four years at Site C and five years at Sites B and D. Degradation of either shield at Site D was superficial or nil for the first year of exposure. The specimen buried at Site C for one year was near ELD on the outer shield at the window and ring areas and perforated due to corrosion at the region adjacent to the ring area. The specimen buried at Site C for four years was ELD on the outer shield at the window and ring areas and the regions adjacent to the window and ring areas. Severe corrosion was observed at the window and ring areas of the specimen buried at Site B for one year, while companion specimens exposed for two and five years were perforated due to corrosion at and adjacent to the window and ring areas. The outer shield of the specimen exposed for five years at Site D was near ELD at the window and ring areas and the region adjacent to the ring area. The outer shield of the specimen exposed for one year at Site G was ELD at the window area; however, and the corrosion of the outer shield at all other rated areas of this specimen was moderate to severe. The outer shield of the specimen buried for two years at Site G was ELD at all areas examined, except the jacketed areas. The specimen exposed for five years at the same site was ELD at all examined areas and was considered destroyed. The specimen exposed for two years at Site D was not recovered.

The filling compound was dry at corroded areas.

System 103. Specimens of this system (Table 1) were exposed only at Sites B, C, D, and E.

The corrosion of both shields was nil or superficial after two years of burial at Site E. Corrosion of the outer shields on specimens buried at Sites B and D after two years of exposure was nil or superficial, while the inner shields of the specimens buried for five years at Site B and D were unaffected by corrosion. The outer shield at the window areas for the specimens buried at Site B for one, two and five years and Site D for five years showed slight localized pitting corrosion, while the same shield of the specimen exposed at Site E showed slight localized pitting corrosion at all areas examined after two years. The outer shield of the specimen exposed at Site C for one year was perforated due to corrosion at the window and ring areas, while the outer shield of the specimen exposed at the same site for four years exhibited perforation due to localized pitting corrosion at the window area and the regions adjacent to the window and ring areas with the ring area near ELD. Corrosion of the inner shield was nil on the specimen exposed at Site C after one year, while after exposure for four years at the same site, the inner shield was ELD at the window and ring areas.

The filling compounds were still tacky.

System 104. Specimens of this system (Table 1) were exposed only at Sites B, C, D, and E.

After exposure for two years at Sites D and E and five years at Site B, the specimens exhibited little or no corrosion on the inner or the outer shields. For the specimen exposed for five years at Site D, the inner shield was unaffected by corrosion, while the outer shield showed slight localized pitting at the window area. The specimen buried at Site C for one year was perforated at the ring area on the outer shield, while the outer shield of the specimen buried at the same site

for four years was ELD at the window and ring areas with very severe corrosion noted at all other areas. The inner shield of the specimen exposed at Site C for one year was unaffected by corrosion, while the companion specimen buried for four years at the same site showed that the inner shield was ELD at all areas examined.

The filling compound was still tacky.

System 105. Specimens of this System (Table 1) were exposed only at Sites B, C, D, and E.

The specimens buried at Site C for one year, Site E for two years, and Sites B and D for five years indicated that both shields were unaffected by corrosion. The specimen exposed for four years at Site C showed that the inner shield was ELD at the window area with severe corrosion occurring at the region adjacent to the window. The same specimen indicated that the outer shield was perforated due to localized pitting corrosion at all areas examined with severe corrosion occurring at the window area.

The filling compounds were still tacky.

DISCUSSION

The data presented describes the performance of various cable systems after exposure for up to seven years in different soil environments. Forty-eight (48) different shielding systems incorporating either metal or plastic coated metals were investigated under some very adverse conditions.

With a few exceptions, direct burial telephone cable specimens containing the various metallic shielding protective systems were prepared with portions of the outer jackets damaged in order to simulate that which could occur in actual field installations. In addition some of the systems were electrically coupled to copper strips, thus creating a galvanic cell between the copper and the noncopper shield materials. This was done to simulate field conditions where the shield may be coupled to existing cable systems having copper shields or to copper ground rods.

Six soil environments which had chemical and physical properties representative of a wide range of soils that may be encountered in the United States in actual field installations were used as the test beds for this study. Some are moderately corrosive and some are very corrosive toward ferrous and other metals or alloys.

The data show that of the cable specimens buried for up to seven years, few were resistant to corrosion in all of the soils in which they were exposed.

The performance of Systems* 56 and 57 after exposure for six years was excellent in alkaline soil. Specimens of System 56 buried in Lakewood sand showed no corrosion after five years of exposure.

Corrosion resistance of the specimens of System 56 exposed for six years were rated fair in clay soil and coastal sand, while corrosion resistance of the specimens of System 57 buried in the same soils was rated poor, as were the specimens exposed in a tidal marsh. Specimens of Systems 56 and 57 were not installed in Hagerstown loam.

Specimens of System 58 exposed for five years had good corrosion resistance in an alkaline soil. However, the corrosion resistance of the specimens of System 59 buried for the same amount of time in the same soil was rated poor. Corrosion resistance of System 60 specimens after four years in coastal sand was very poor and the same was true for specimens exposed in alkaline soil for five years. Similarly, the corrosion resistance of the specimens of System 58 buried for five years in coastal sand and System 61 in alkaline soil were noted as performing poorly. After exposure for six years, specimens of Systems 58, 59, 60, and 61 exhibited poor resistance to corrosion in clay soil and tidal marsh as did specimens of Systems 59 and 61 buried for the same time in coastal sand. Specimens of Systems 58, 59, 60, and 61 were not installed in Hagerstown loam and Lakewood sand.

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*Systems are described in Table 1.

After exposure for five years in an alkaline soil, six years in clay and Lakewood sand, and four to six years in Hagerstown loam, there was little or no corrosion of specimens of Systems 62, 63, 64, 65, and 66. Similarly, there was no corrosion of specimens of System 65 after exposure for up to six years in a tidal marsh. The corrosion performance of Systems 62, 63, and 64 exposed in a tidal marsh was fair. Specimens of System 66 were not buried in this soil.

Specimens of Systems 67, 68, and 69 buried for three years in an alkaline soil and five years in Hagerstown loam, clay and Lakewood sand were unaffected by corrosion. The corrosion resistance of the specimens of System 70 exposed for three years in alkaline soil was poor, while the performance of the specimens buried in Hagerstown loam, clay, and Lakewood sand were rated as excellent. Systems 67, 68, 69, and 70 were not installed in coastal sand or tidal marsh.

After exposure for four years in coastal sand, the corrosion resistance of System 73 was generally rated as poor. The resistance to corrosion of the specimens of Systems 73 and 74 (same as System 73 except coupled to copper) buried in alkaline soil were rated poor to very poor. Similarly, companion specimens of the same systems exposed for four years in Hagerstown loam and coastal sand and seven years in clay, Lakewood sand and a tidal marsh, performed poorly.

The corrosion resistance of the specimens of System 75 buried for two years in an alkaline soil, four years in coastal sand, and seven years in clay and Lakewood sand ranged from good to excellent. The specimens exposed for seven years in a tidal marsh had very poor corrosion resistance. System 75 exposed in Hagerstown loam had good corrosion resistance after four years of exposure. The resistance to

corrosion of the System 76 specimens (same as System 75 except coupled to copper) buried for four years in Hagerstown loam and coastal sand and buried for seven years in clay, Lakewood sand and a tidal marsh were rated fair to very poor.

The corrosion performance of System 77 exposed for two years in an alkaline soil was good, while that of System 78 (same as System 77 except coupled to copper) was poor to very poor. Corrosion of System 77 specimens buried for four years in Hagerstown loam were rated poor while specimens of System 78 under the same conditions were judged to be in poor to very poor condition. Corrosion resistance of Systems 77 and 78 were rated poor to very poor in coastal sand after an exposure of four years and in clay soil, Lakewood sand and tidal marsh after an exposure of seven years.

For the specimens of System 79 exposed for two years in an alkaline soil there was little or no corrosion observed. The corrosion performance of System 80 (same as System 79 except coupled to copper) buried for two years in an alkaline soil was rated fair, as was System 79 exposed for three years in coastal sand. The performance of specimens of System 79 buried for four years in Hagerstown loam was fair to poor, while companion specimens of the same system buried for seven years in clay soil and Lakewood sand were rated fair to very poor. The corrosion resistance of System 79 in a tidal marsh was poor to very poor after seven years of exposure. The corrosion performance of System 80 in Hagerstown loam and coastal sand after four years of exposure and in clay, Lakewood sand, and tidal marsh after seven years of exposure was rated poor to very poor.

There was no corrosion on System 81 buried in alkaline soil for two years. However, the corrosion resistance of System 82 (same as System 81 except coupled to copper) exposed in the same soil and for the same length of time was observed as poor. The corrosion performance of the specimens of System 81 exposed in coastal sand for four years was rated fair while the performance of the specimens of the same system exposed in Lakewood sand for seven years ranged from fair to very poor. The System 81 specimens buried in Hagerstown loam and System 82 in Lakewood and coastal sand had poor corrosion resistance. The corrosion resistance of System 81 in clay soil and tidal marsh was very poor as was the corrosion resistance of the specimens of System 82 in Hagerstown loam and clay soil. Specimens of System 82 exposed in tidal marsh for seven years were considered destroyed.

Systems 83 and 84 were unaffected by corrosion after being exposed for two years in an alkaline soil. System 83 remained generally unaffected by corrosion after four years in Hagerstown loam and coastal sand and after seven years in Lakewood sand. The resistance to corrosion of the specimens of System 84 (same as System 83 except coupled to copper) buried in coastal sand for four years was good while that of companion specimens in Hagerstown loam was noted as moderate to poor. The System 84 specimens buried in Lakewood sand for seven years had good to very poor corrosion resistance. The condition of both systems were poor to very poor with respect to corrosion in clay soil and tidal marsh after being buried for seven years.

For specimens of System 85 exposed in an alkaline soil for two years, no corrosion was observed. However, corrosion of System 86 (same as System 85 except coupled to copper) buried in the same soil for the

same time was moderate. Specimens of System 85 after exposure for four years in Hagerstown loam and after exposure for seven years in clay and Lakewood sand exhibited poor to very poor corrosion resistance. The resistance to corrosion of the System 85 specimens exposed for four years in coastal sand was rated fair to poor. Specimens of System 86 were found to be severely corroded after four years exposure in Hagerstown loam and coastal sand and after seven years exposure in clay and Lakewood sand. Both systems were destroyed due to exposure in tidal marsh after seven years.

The corrosion of Systems 87 and 88 buried for two years in an alkaline soil was moderate. System 87 specimens exposed in coastal sand performed well, while System 88 (same as System 87 except coupled to copper) specimens performed very poorly after four years of exposure. Corrosion resistance of both systems was poor to very poor after being buried for four years in Hagerstown loam and after being buried for seven years in Lakewood sand. Severe corrosion was noted for specimens of Systems 87 and 88 exposed in a tidal marsh and specimens of System 88 exposed in a clay soil. The specimens of both systems were considered destroyed after seven years of exposure in clay and tidal marsh.

Specimens of Systems 89 and 90 buried in an alkaline soil for one year and three years in all other soil environments showed little or no corrosion attack except in a tidal marsh where corrosion resistance was generally good. The corrosion resistance of Systems 91 and 92 in Hagerstown loam and System 91 in Lakewood sand was very poor after an exposure of three years. Specimens of both Systems 91 and 92 were considered destroyed after exposure in alkaline soil for one year and tidal marsh for three years. Specimens of System 91 were also destroyed

after three years in clay soil and coastal sand. There were no specimens of System 92 installed in clay soil, Lakewood, or coastal sand.

The specimens of System 93 buried for three years in Hagerstown loam and clay soil were observed to be in generally good condition. The corrosion resistance of the specimens of System 93 after exposure for one year in an alkaline soil was rated very poor as was the corrosion resistance of the specimens exposed for three years in Lakewood and coastal sand. Specimens of System 94 (same as System 93 except coupled to copper) buried in the same soil for one year and buried in Hagerstown loam for two years were destroyed due to corrosion. Specimens of System 93 were not installed in a tidal marsh, nor was System 94 installed in clay soil, Lakewood sand, coastal sand, or tidal marsh.

The specimens of System 95 exposed for two years in coastal sand, four years in clay soil, and five years in Hagerstown loam and Lakewood sand had corrosion resistance that ranged from good to excellent, while the corrosion resistance of the specimens buried in tidal marsh for two years was rated as good. The specimen buried for five years in the tidal marsh was considered destroyed.

The corrosion performance of specimens of System 96 buried for five years in Hagerstown loam and Lakewood sand was good to fair. Specimens exposed for four years in clay soil and two years in coastal sand exhibited poor to very poor corrosion performance. The specimen exposed in tidal marsh for five years was considered destroyed.

Specimens of System 97 exposed for four years in clay soil, five years in Hagerstown loam and Lakewood sand and two years in coastal sand

had little or no corrosion. The specimen buried in tidal marsh for five years had very poor resistance to corrosion.

For System 98, the specimens exposed for five years in Hagerstown loam and Lakewood sand showed good to fair corrosion performance. The corrosion performance of specimens buried for four years in clay soil and for two years in coastal sand was very poor. The specimen buried in tidal marsh for five years was considered destroyed.

Specimens of System 99 after exposure for four years in clay soil, five years in Hagerstown loam, and two years in coastal sand had excellent corrosion resistance. Specimens buried for five years in Lakewood sand and tidal marsh had corrosion resistance that ranged from fair to very poor.

The corrosion resistance of specimens of System 100 buried for four years in clay soil, five years in Hagerstown loam, and Lakewood sand and two years in tidal marsh was rated as fair to very poor, while the corrosion performance of the specimen exposed in coastal sand for two years was rated as good. The specimen in the tidal marsh was considered destroyed after five years of exposure.

The corrosion performance of specimens of System 101 exposed for four years in clay soil, five years in Hagerstown loam and Lakewood sand and two years in coastal sand was rated good. However, the corrosion resistance of the specimens buried in tidal marsh for five years was rated very poor.

For System 102, the corrosion resistance of the specimens was poor to very poor in coastal sand and tidal marsh after two years of exposure and in Hagerstown loam and Lakewood sand after five years of exposure. After five years of exposure in tidal marsh the specimen was considered destroyed.

The corrosion performance of specimens of System 103 exposed for two years in coastal sand and five years in Hagerstown loam and Lakewood sand was rated as good. For the specimens buried in clay soil for four years the corrosion resistance rating ranged from good to very poor. No specimens of this system were exposed at Site G.

For System 104, the corrosion resistance was good to excellent in coastal sand after two years of exposure and in Hagerstown loam and Lakewood sand after five years of exposure. The specimens buried in clay soil for four years had a corrosion rating of good to very poor. No specimens of this system were exposed at Site G.

The corrosion resistance of the specimens of System 105 exposed for one year in clay, two years in coastal sand, and five years in Hagerstown loam and Lakewood sand was excellent. The corrosion resistance of the specimen exposed in clay soil after four years was rated very poor. No specimens of this system were exposed to tidal marsh.

SUMMARY

The following should not be considered for use because of the relatively poor performance in one or more of the less aggressive soils: Systems No. 56, 58, 60, 61, 73, 77, 79, 81, 85, 87, 91, and 93.

When Systems No. 57, 59, 74, 76, 78, 80, 82, 84, 86, 88, 92, 94, 96, 100, and 102 were coupled to copper, their performance was poor to very poor in one or more of the soils. For most of the materials studied in this investigation, the copper strip coupled to the shield caused an appreciable acceleration of corrosion to the shield over that observed when the material was not coupled to copper. The copper behaved as the cathode in a galvanic cell where the dissimilar metal shield was the anode. The result was dissipation of the shield by sacrificial corrosion in addition to the normal corrosion occurring in the particular soil environment.

Some exceptions to the above were noted where some specimens fabricated with stainless steel shields were coupled to copper, i.e., Systems No. 57 and 59. For these specimens, the copper was anodic to the stainless steel outer shield and cathodic to the inner aluminum shield. With the exception of one specimen, there was little or no degradation of the copper strips buried in any of the soils; however, some green patina was observed on areas on all of the copper strips.

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Tables

Table 1 Description of Various Systems Included in the Soil Corrosion Study of Telephone Cable Shielding Materials

Table 2 Properties of the Soils at the Test Sites

Table 3 Rating Code for the Corrosion Evaluation of Shields in Cable Specimens

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Table 8 Performance of Shields in Cable Specimens Buried for Up to Six Years in Coastal Sand (Site E)

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Figure Captions

Figure 1	Preparation of specimens for cable exposure tests.
Figure 2 & 3	Systems 95, 96, 97, 98, 99, and 100 exposed at Site C for four years.
Figure 4 & 5	Systems 101, 102, 103, 104, and 105 exposed at Site C for four years.
Figure 6	System 95 exposed for five years.
Figure 7	System 96 exposed for five years.
Figure 8	System 97 exposed for five years.
Figure 9	System 98 exposed for five years.
Figure 10 & 11	System 99 exposed for five years.
Figure 12 & 13	System 100 exposed for five years.
Figure 14 & 15	System 101 exposed for five years.
Figure 16	System 102 exposed for five years.
Figures 17 - 48	Systems 73 thru 88 exposed for seven years.

Table 1. Description of Various Systems Included in the Soil Corrosion Study of Telephone Cable Shielding Materials

System	Description
56	3-mil (0.08 mm) Type 430 stainless steel outer shield bonded to a 3-mil (0.08 mm) 1100 aluminum alloy inner shield with a clear flooding compound on the core side.
57	Same as System 56, except that the system was coupled to copper.
58	3-mil (0.08 mm) Type 304 stainless steel with 4-mil (0.10 mm) vapor deposited aluminum on the outer surface.
59	Same as System 58, except that the shield was coupled to copper.
60	3-mil (0.08 mm) Type 304 stainless steel with 2-mil (0.05 mm) vapor deposited aluminum on the outer and core sides of the shield.
61	Same as System 60, except that the shield was coupled to copper.
62	50-pair, 22-gauge air core cable having an 8-mil (0.20 mm) aluminum alloy shield with a copolymer coating on both sides of the shield. Cable core was removed.
63	16-pair, 22-gauge cable having an 8-mil (0.20 mm) uncorrugated aluminum alloy shield bonded on both sides to a polyolefin polymer. Shield was bonded to the jacket.
64	25-pair, 18-gauge cable having an 8-mil (0.20 mm) uncorrugated aluminum alloy shield bonded on both sides to a 2-mil (0.05 mm) polyolefin polymer. Shield was bonded to the jacket.
65	25-pair, 24-gauge cable having an 8-mil (0.20 mm) uncorrugated aluminum alloy shield bonded on both sides to a polyolefin polymer. Shield was bonded to the jacket.
66	Same as System 65, except that the shield was coupled to copper.
67	4-mil (0.10 mm) aluminum foil 3 3/4 in. x 8 in. (9.52 cm x 20.32 cm) coated both sides with a 6-mil (0.15 mm) ethylene acrylic acid coploymer
68	4-mil (0.10 mm) aluminum foil 3 3/4 in x 8 in. (9.52 cm x 20.32 cm) coated both sides with a 6-mil (0.15 mm) polyester film.
69	4-mil (0.10 mm) aluminum foil 1 1/2 in. x 12 in. (3.81 cm x 30.48 cm) coated both sides with a 5.5 mil (0.14 mm) polyester film.
70	25-pair, 24-gauge cable having a 6-mil (0.15 mm) corrugated copper alloy outer shield (nominal chemical composition: 97.5 percent Cu, 2.5 percent Fe, 0.02 percent P) and an inner shield of 4-mil

Table 1 (continued)

System	Description
	(0.10 mm) aluminum alloy coated on both sides with a 5.5-mil (0.14 mm) polyester film. Outer shield was bonded to the jacket. This was a filled cable having a clear flooding compound.
73	25-pair, 22-gauge cable having a 6-mil (0.15 mm) corrugated black plate steel outer shield and an 8-mil (0.20 mm) corrugated aluminum alloy inner shield coated on both sides with a 2-mil (0.05 mm) ethylene acrylic acid copolymer. This was a filled cable having a clear flooding compound over the core and inner shield and another type of clear flooding compound over the outer shield.
74	Same as System 73, except that the shields were coupled to copper.
75	25-pair, 22-gauge cable having a 6-mil (0.15 mm) corrugated steel outer shield, coated on both sides with a 2-mil (0.05 mm) ethylene acrylic acid copolymer and an 8-mil (0.20 mm) corrugated aluminum alloy inner shield, coated on both sides with a 2-mil (0.05 mm) ethylene acrylic acid copolymer. This was a filled cable having a clear flooding compound over the core and inner shield and another type of clear flooding compound over the outer shield.
76	Same as System 75, except that the shields were coupled to copper.
77	25-pair, 22-gauge cable having a 6-mil (0.20 mm) corrugated steel outer shield and an 8-mil (0.20 mm) corrugated aluminum alloy inner shield coated on both sides with a 2-mil (0.05 mm) ethylene acrylic acid copolymer. This was a filled cable having a clear flooding compound over the core and inner shield and another type of clear flooding compound over the outer shield.
78	Same as System 77, except that the shields were coupled to copper.
79	25-pair, 22-gauge cable having a 6-mil (0.15 mm) corrugated steel outer shield and an 8-mil (0.20 mm) corrugated aluminum alloy inner shield. This was a filled cable having a clear flooding compound over the core and inner shield and another type of clear flooding compound over the outer shield.
80	Same as System 79, except that the shields were coupled to copper.
81	25-pair, 22-gauge cable having a 6-mil (0.15 mm) corrugated steel outer shield and an 8-mil (0.20 mm) corrugated aluminum alloy inner shield coated on both sides with 2-mil (0.05 mm) ethylene acrylic acid copolymer. This was a filled cable with amophous polypropylene applied over the core, inner shield, and outer shield.
82	Same as System 81, except that the shields were coupled to copper.

Table 1 (continued)

System	Description
83	25-pair, 22-gauge cable having a 6-mil (o.15 mm) corrugated steel outer shield coated on both sides with 2-mil (0.05 mm) ethylene acrylic acid copolymer and an 8-mil (0.20 mm) corrugated aluminum alloy inner shield coated on both sides with ethylene acrylic acid copolymer. This was a filled cable with amorphous polypropylene applied over the core, inner shield, and outer shield.
84	Same as System 83, except that the shields were coupled to copper.
85	25-pair, 22-gauge cable having a 6-mil (0.15 mm) corrugated steel outer shield and an 8-mil (0.20 mm) corrugated aluminum alloy shield. This was a filled cable with amorphous polypropylene applied over core, inner shield, and outer shield.
86	Same as System 85, except that the shields were coupled to copper.
87	25-pair, 22-gauge cable having a 6-mil (0.15 mm) corrugated black plate steel outer shield and an 8-mil (0.20 mm) corrugated aluminum alloy inner shield coated on both sides with a 2-mil (0.05 mm) ethylene acrylic acid copolymer. This was a filled cable with amorphous polypropylene applied over core, inner shield, and outer shield.
88	Same as System 87, except that the shields were coupled to copper.
89	100-pair, 22-gauge semi-conducting cable having a 5-mil (0.13 mm) corrugated copper alloy shield and a low density polyethylene jacket.
90	Same as System 89, except that the shield was coupled to copper.
91	A corrugated 3-mil (0.08 mm) 1006 low carbon steel inner shield bonded to a 3-mil (0.08 mm) 4022 aluminum alloy outer shield.
92	Same as System 91, except that the shields were coupled to copper.
93	A corrugated 3-mil (0.08 mm) 1006 low carbon steel inner shield bonded to a 3-mil (0.08 mm) 4022 aluminum alloy outer shield.
94	Same as System 93, except that the shields were coupled to copper.
95	A coaxial cable consisting of a 25-mil (0.64 mm) uncorrugated seamless aluminum alloy outer shield and a 112-mil (2.84 mm) solid copper alloy center conductor with a high density polyethylene jacket.
96	Same as System 95, except that the outer shield was coupled to copper.

Table 1 (continued)

System	Description
97	A coaxial cable consisting of a 25-mil (0.64 mm) uncorrugated seamless aluminum alloy outer shield and a 112-mil (2.84 mm) solid copper alloy center conductor. This was a filled cable having a flooding compound of polyisobutylene between jacket and outer shield, with a high density polyethylene jacket.
98	Same as System 97, except that the outer shield was coupled to copper.
99	25-pair, 22-gauge cable having a 6-mil (0.15 mm) corrugated tin free steel outer shield, coated on both sides with a 2-mil (0.05 mm) ethylene acrylic acid copolymer and an 8-mil (0.20 mm) corrugated aluminum alloy inner shield, coated on both sides with a 2-mil (0105 mm) ethylene acrylic acid copolymer. This was a filled cable having a clear flooding compound over the core and inner shield, and another type of clear flooding compound over the outer shield.
100	Same as System 99, except that the shields were coupled to copper.
101	6-mil (0.15 mm) corrugated tin plated steel outer shield coated on both sides with a 2-mil(0.05 mm) ethylene acrylic acid copolymer and a 25-mil 9).64 mm) uncorrugated seamless aluminum alloy inner shield (outer conductor) have a 98-mil (2.49 mm) solid copper alloy center conductor with a polyethylene inner and outer jacket.
102	Same as System 101, except outer shield was coupled to copper.
103	25-pair, 22-gauge cable having a corrugated aluminum alloy outer shield bonded to a corrugated low carbon steel inner shield coated only on the inner shield. This was a filled cable having a clear flooding compound on the outer and inner shields.
104	25-pair, 22 gauge cable having a corrugated aluminum alloy outer shield bonded to a corrugated low carbon steel inner shield. This was a filled cable having a clear flooding compound on the outer and inner shields.
105	25-pair, 22 gauge cable having a corrugated aluminum alloy outer shield bonded to a corrugated low carbon steel inner shield coated on both the outer and inner shields. This was a filled cable having a clear flooding compound on the outer and inner shields.

Table 2. Properties of Soils at Test Sites

Site Ident.	Soil	Location	Internal drainage of test site	Resistivity[1] (ohm - cm)	pH	TDS[2]	Composition of water extract (parts per million) Ca	Mg	Na + K as Na	CO_3	HCO_3	SO_4	Cl	NO_3
A	Sagemoor sandy loam	Toppenish, WA	Good	400	8.8	7,080	108	23	1,960	0.0	5,002	216	330	6
B	Hagerstown loam	Loch Raven, MD	Good	5,200	5.8	[3]	--	--	--	--	--	--	--	--
C	Clay	Cape May, NJ	Poor	300	4.0	14,640	540	754	2,242	0.0	0.0	6,768	3,529	118
D	Lakewood sand	Wildwood, NJ	Good	30,000	7.3	[3]	--	--	--	--	--	--	--	--
E	Coastal sand	Wildwood, NJ	Poor	55	7.1	11,010	302	329	3,230	0.0	55	1,333	5,765	31
G	Tidal marsh	Lexington Park, MD	Poor	300	7.1	11,580	140	165	2,392	0.0	0.0	1,709	3,259	37
							(Milligram equivalents per 100 grams of soil)							
A	---	---	---	---	---	---	0.54	0.19	8.50	0.0	8.20	0.45	0.93	0.0
B	---	---	---	---	---	[3]	---	---	---	---	---	---	---	--
C	---	---	---	---	---	---	2.70	6.18	9.51	0.0	0.0	14.0	9.94	0.1
D	---	---	---	---	---	[3]	---	---	---	---	---	---	---	--
E	---	---	---	---	---	---	1.51	2.70	13.9	0.0	0.09	2.36	16.2	0.0
G	---	---	---	---	---	---	0.70	1.35	10.2	0.0	0.0	2.56	9.18	0.0

[1]Resistivity determinations made at the test site with Shepard Canes
[2]TDS, total dissolved solids--residue dried at 105 °C
[3]Analyses not made for soils at sites B and D because of the very low concentrations of soluble salts in these soils

Table 3. Rating Code for the Corrosion Evaluation of Shields in Cable Specimens

Rating	Performance	Degree of Corrosion
10	Excellent	Unaffected. No indication of corrosion.
9	Excellent	Superficial rust or etching on surface.
8	Very Good	Uniform metal attack, rust, and/or slight localized pitting.
7	Good	Appreciable pitting over the surface, but no perforations through metal shield. Some minor delamination or dissipation of metallurgically or plastic-bonded metals leaving cathodic metal intact.
6+	Good	Localized pitting: only one perforation in shield by pitting.
6	Good	Localized pitting: two to five perforations in shield by pitting.
5	Fair	Many localized pits causing perforation of shield; less than 5 percent of shield dissipated by corrosion; extensive delamination of metallurgically bonded metals.
4	Poor	Severe corrosion: pitting to perforation of shield; five to ten percent of shield dissipated by corrosion of anodic part of metallurgically bonded metals.
3	Poor	Severe corrosion: pitting to perforation of shield; ten to twenty-five percent of shield dissipated by corrosion.
2	Very Poor	Severe corrosion: more than twenty-five percent of shield dissipated by corrosion: shield still has electrical continuity along the cable.
1	Very Poor	Severe corrosion: shield is close to electrical discontinuity (ELD) due to perforation in shield and dissipation of metal by corrosion.
0	Very Poor	Severe corrosion: shield is electrically discontinuous (ELD) due to dissipation of metal by corrosion.

Table 4. Performance of Shields in Cable Specimens Buried Up to Six Years in Sagemoor Sandy Loam (Site A)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
56	1	10	10	10	10	10	
	2	10	10	10	10	10	
	3	10	10	10	10	10	
	4	10	10	10	10	10	
	5	10	10	10	10	10	
	6	10	10	10	10	10	
57	1	10(4)	10(5)	10	10(5)	10(5)	10
	2	10	10	10	10	10	10
	3	10	10	10	10	10	10
	4	10	10	10	10	10	10
	5	10	10	10	10	10	10
	6	10	10	10	10	10	9
58	1	10(5)	10(5)	10(0)	10(5)	10(7)	
	2	10(5)	10(4)	10(0)	10(5)	10(5)	
	3	10(5)	10(5)	10(0)	10(7)	10(7)	
	4	10(10)	10(10)	10(5)	10(7)	10(7)	
	5	10(7)	10(7)	10(7)	10(7)	10(7)	
59	1	10(0)	10(2)	10(2)	10(0)	10(3)	9
	2	10(0)	10(2)	6(10)	10(0)	10(1)	9
	3	9(0)	9(2)	9(0)	10(0)	9(2)	10
	4	9(5)	9(4)	9(0)	9(7)	9(5)	9
	5	9(5)	10(4)	9(5)	9(3)	9(5)	10
60	1	0(10)5	0(10)5	0(10)5	0(10)5	0(10)3	
	2	0(10)8	1(10)8	0(10)0	1(10)7	0(10)7	
	3	0(10)4	1(10)3	0(10)0	0(10)2	0(10)5	
	4	1(10)5	2(10)7	0(10)0	1(10)7	1(10)7	
	5	1(10)7	1(10)8	1(10)7	1(10)7	7(10)8	
61	1	0(10)1	0(10)0	0(10)1	0(10)3	0(10)5	9
	2	1(10)5	1(10)5	0(10)0	0(10)2	0(10)3	10
	3	0(10)0	1(10)4	0(5)0	0(10)2	1(10)2	10
	4	0(10)4	0(10)1	0(10)5	0(10)5	0(10)5	10
	5	0(10)0	0(10)3	0(10)0	0(10)0	0(10)3	9

Table 4 (Site A continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
62	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
63	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
64	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
65	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
66	1			10			10
	2			10			9
	3			10			Missing
	4			10			10
	5			10			Missing
67	1			10			
	2			10			
	3			10			
68	1			10			
	2			10			
	3			10			
69	1			10			
	2			10			
	3			10			
70	1			10			
	2			10			
	3			3			

Table 4 (Site A continued)

System	Exposure Time (years)	Exposed window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
73	1	9(10)	9(10)	9(10)	9(10)	9(10)	
	2	4(10)	2(10)	9(10)	8(10)	8(10)	
74	1	2(9)	1(9)	9(10)	5(9)	3(9)	10
	2	4(10)	2(10)	9(10)	8(10)	8(10)	10
75	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	8(10)	8(10)	10(10)	10(10)	10(10)	
76	1	10(10)	10(10)	10(10)	10(10)	10(10)	10
	2	8(10)	6+(10)	10(10)	10(10)	10(10)	10
77	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	6(10)	6(10)	10(10)	10(10)	10(10)	
78	1	10(10)	10(10)	10(10)	10(10)	10(10)	10
	2	4(10)	1(10)	10(10)	10(8)	10(8)	10
79	1	10(10)	6(10)	10(10)	10(10)	10(10)	
	2	9(10)	10(10)	10(10)	10(10)	10(10)	
80	1	10(10)	5(6)	9(10)	10(10)	9(10)	10
	2	4(4)	4(4)	10(10)	10(5)	10(10)	10
81	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
82	1	6(10)	5(10)	10(10)	10(10)	10(10)	10
	2	4(2)	3(5)	9(10)	8(10)	8(10)	10
83	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
84	1	Not recovered					
	2	10(10)	10(10)	10(10)	10(10)	10(10)	10
85	1	9(10)	9(10)	10(10)	10(10)	10(10)	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
86	1	5(10)	6(10)	10(10)	10(10)	10(10)	10
	2	5(10)	5(10)	10(10)	10(10)	10(10)	10
87	1	9(10)	9(10)	10(10)	10(10)	9(10)	
	2	6(10)	5(10)	10(10)	10(10)	10(10)	
88	1	6(10)	5(10)	10(10)	10(10)	10(10)	10
	2	8(10)	5(10)	10(10)	8(10)	10(10)	10

Table 4 (Site A continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
89	1	9	9	10	10	10	
90	1	9	9	10	10	9	10
91	1	Destroyed					
92	1	Destroyed					
93	1	5(0)	5(0)	5(4)	5(0)	5(0)	
94	1	Destroyed					

Table 5. Performance of Shields in Cable Specimens Buried Up to Seven Years in Hagerstown Loam (Site B)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
62	1			10			
	2			10			
	3			10			
	4			10			
63	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
	6			10			
64	1			10			
	2			10			
	3			10			
	4			10			
65	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
	6			10			
66	1			10			10
	2			10			10
	3			10			10
	4			10			Missing
	5			10			Missing
	6			10			9
67	1			10			
	2	Not recovered					
	3			10			
	4			10			
	5			10			
68	1			10			
	2			10			
	3			10			
	4			10			
	5			10			

Table 5 (Site B continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
69	1			10			
	2	Not recovered					
	3			10			
	4			10			
	5			10			
70	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
73	1	2(10)	2(10)	10(10)	9(10)	9(10)	
	2	4(10)	3(10)	9(10)	8(10)	8(10)	
	3	2(10)	1(10)	8(10)	8(10)	8(10)	
	4	1(10)	2(10)	7(10)	6+(10)	7(10)	
	7	Not recovered					
74	1	0(10)	1(10)	9(10)	9(10)	5(10)	10
	2	3(10)	2(10)	9(10)	8(10)	10(10)	10
	3	0(10)	1(10)	8(10)	2(10)	3(10)	9
	4	1(7)	0(5)	5(10)	5(10)	1(10)	9
	7	Not Recovered					
75	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
	3	6+(10)	6+(10)	10(10)	10(10)	10(10)	
	4	5(10)	8(10)	10(10)	10(10)	10(10)	
	7	Not Recovered					
76	1	5(10)	5(10)	10(10)	5(10)	5(10)	10
	2	5(10)	5(10)	10(10)	5(10)	10(10)	10
	3	3(10)	4(10)	10(10)	5(10)	7(10)	10
	4	1(10)	6(10)	10(10)	5(10)	7(10)	9
	7	Not Recovered					
77	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	5(10)	6(10)	8(10)	8(10)	9(10)	
	3	4(10)	6+(10)	8(10)	8(10)	9(10)	
	4	2(10)	6+(10)	6+(10)	6(10)	6(10)	
	7	Not Recovered					
78	1	2(10)	2(10)	10(10)	9(10)	9(10)	10
	2	1(10)	1(10)	10(10)	8(10)	8(10)	10
	3	0(10)	0(10)	6(10)	2(10)	2(10)	10
	4	0(10)	0(10)	6(10)	0(10)	0(10)	9
	7	Not Recovered					

Table 5 (Site B continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
79	1	6(10)	5(10)	10(10)	10(10)	10(10)	
	2	5(10)	5(10)	9(10)	8(10)	8(10)	
	3	4(10)	3(10)	8(10)	8(10)	8(10)	
	4	4(10)	3(10)	8(10)	5(10)	8(10)	
	7	Not Recovered					
80	1	2(10)	2(10)	9(10)	9(10)	10(10)	10
	2	2(6+)	1(9)	8(9)	8(10)	9(10)	10
	3	0(4)	0(4)	5(10)	4(10)	5(10)	10
	4	0(4)	0(3)	8(9)	4(9)	5(9)	9
	7	Not Recovered					
81	1	9(10)	5(10)	9(10)	9(10)	9(10)	
	2	3(10)	4(10)	9(10)	9(10)	9(10)	
	3	4(10)	9(10)	5(10)	6(10)	6+(10)	
	4	3(10)	4(10)	6(10)	7(10)	6(10)	
	7	Not Recovered					
82	1	2(10)	2(10)	9(10)	9(10)	9(10)	9
	2	1(10)	1(10)	9(10)	8(10)	8(10)	10
	3	1(10)	1(10)	8(10)	2(10)	2(10)	9
	4	1(10)	1(10)	7(10)	5(10)	3(10)	9
	7	Not Recovered					
83	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
	3	10(10)	10(10)	10(10)	10(10)	10(10)	
	4	10(10)	8(10)	10(10)	10(10)	10(10)	
	7	Not Recovered					
84	1	5(10)	5(10)	10(10)	10(10)	8(10)	10
	2	6(10)	6(10)	10(10)	10(10)	10(10)	10
	3	3(10)	5(10)	10(10)	10(10)	10(10)	9
	4	3(10)	3(10)	10(10)	5(10)	4(10)	9
	7	Not Recovered					
85	1	9(10)	4(10)	9(10)	4(10)	9(10)	
	2	6(10)	4(10)	10(10)	8(10)	9(10)	
	3	4(10)	4(10)	8(10)	8(10)	8(10)	
	4	4(10)	3(10)	9(10)	6(10)	9(10)	
	7	Not Recovered					
86	1	3(9)	3(9)	10(9)	9(9)	9(9)	10
	2	2(10)	1(10)	10(10)	8(10)	10(10)	10
	3	1(6)	2(6)	9(6)	8(6)	9(6)	10
	4	1(6)	1(6)	9(6)	5(6)	6+(7)	9
	7	Not Recovered					

Table 5 (Site B continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
87	1	5(10)	5(10)	9(10)	8(10)	8(10)	
	2	4(10)	4(10)	9(10)	8(10)	8(10)	
	3	3(10)	3(10)	8(10)	6(10)	8(10)	
	4	3(10)	2(10)	8(10)	5(10)	4(10)	
	7	Not Recovered					
88	1	3(10)	3(10)	8(10)	8(10)	8(10)	10
	2	2(10)	1(10)	8(10)	8(10)	8(10)	10
	3	2(10)	0(10)	7(10)	7(10)	7(10)	10
	4	2(10)	0(10)	7(10)	2(10)	4(10)	9
	7	Not Recovered					
89	1	9	9	9	9	9	
	2	9	9	9	9	9	
	3	9	9	9	9	9	
90	1	9	9	9	9	9	10
	2	9	9	9	9	9	9
	3	9	9	9	9	9	9
91	1	4(5)	3(8)	8(9)	6(9)	7(9)	
	2	0(9)	3(9)	8(9)	7(9)	3(9)	
	3	0(6)	0(6)	5(5)	6(6)	6(6)	
92	1	Destroyed					Missing
	2	0(4)	0(3)	7(7)	4(6)	0(5)	10
	3	0(0)	0(0)	5(5)	5(5)	5(5)	9
93	1	9(6)	9(7)	9(7)	9(7)	9(7)	
	2	9(7)	9(7)	9(7)	9(7)	9(7)	
	3	7(7)	5(5)	6+(6+)	6(6)	7(7)	
94	1	Destroyed					10
	2	Destroyed					10
	3	Destroyed					Missing
95	1	9	9	10	10	10	
	2	9	9	10	10	10	
	5	10	9	10	10	10	
96	1	8	8	10	8	8	10
	2	7	7	9	8	8	9
	5	8	9	9	9	9	9
97	1	10	10	10	10	10	
	2	10	10	10	10	10	
	5	10	10	10	10	10	

Table 5 (Site B continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
98	1	8	8	10	10	10	10
	2	7	7	7	7	7	9
	5	8	8	8	7	6+	8
99	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
	5	10(10)	10(10)	10(10)	10(10)	10(10)	
100	1	5(10)	6(10)	10(10)	10(10)	10(10)	9
	2	2(10)	3(10)	10(10)	4(10)	10(10)	9
	5	5(10)	5(10)	10(10)	10(10)	10(10)	8
101	1	8(10)	8(10)	8(10)	8(10)	8(10)	
	2	7(10)	6+(10)	8(10)	7(10)	7(10)	
	5	7(10)	8(10)	8(10)	9(10)	9(10)	
102	1	4(10)	4(10)	10(10)	9(10)	9(10)	9
	2	3(10)	5(10)	10(10)	6(10)	5(10)	9
	5	2(10)	4(10)	7(10)	5(10)	6(10)	8
103	1	8	10	10	10	10	
	2	8(10)	10(10)	10(10)	10(10)	10(10)	
	5	7(10)	8(10)	10(10)	10(10)	10(10)	
104	1	10	10	10	10	10	
	2	9(10)	10(10)	10(10)	10(10)	10(10)	
	5	8(10)	8(10)	10(10)	10(10)	10(10)	
105	1	10	10	10	10	10	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
	5	10(10)	10(10)	10(10)	10(10)	10(10)	

Table 6. Performance of Shields in Cable Specimens Buried Up to Seven Years in Clay Soil (Site C).

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
56	1	10	10	10	10	10	
	2	10	10	10	10	10	
	3	10	10	10	10	10	
	4	10(2)	10	10	10	10	
	5	10	10	10	10	10	
	6	10(5)	10(5)	10(5)	10(5)	10(5)	
57	1	10	10	10	10	10	9
	2	10(5)	10(5)	10	10(5)	10(5)	Missing
	3	10(5)	10(5)	10	10	10	Missing
	4	10(0)	10	10	10	10	10
	5	10(0)	3(2)	10(0)	10(0)	10(3)	9
	6	6(0)	10(0)	10(0)	9(0)	10(0)	9
58	1	10(5)	10(5)	10(4)	10(7)	10(8)	
	2	10(2)	9(3)	10(4)	10(5)	9(5)	
	3	9(2)	9(5)	10(0)	10(4)	10(7)	
	4	9(5)	7(7)	9(1)	9(5)	9(7)	
	5	8(4)	6+(5)	10(2)	9(5)	6+(5)	
	6	9(1)	9(0)	9(0)	9(0)	9(1)	
59	1	9(3)	10(2)	10(3)	10(5)	10(2)	Missing
	2	10(1)	10(0)	10(0)	10(0)	10(0)	9
	3	10(0)	10(0)	5(0)	10(0)	10(0)	10
	4	10(0)	8(0)	5(0)	9(0)	6+(0)	Missing
	5	9(0)	5(0)	10(0)	9(0)	10(0)	Missing
	6	6+(0)	6+(0)	3(0)	6+(0)	6(0)	5
60	1	4(10)7	6(6)6	4(10)1	5(10)5	5(10)5	
	2	0(10)5	0(10)8	3(10)2	7(10)5	2(10)5	
	3	1(10)7	2(10)7	0(10)0	2(10)5	2(10)8	
	4	0(10)7	0(10)8	4(10)1	2(10)5	3(10)7	
	5	0(10)0	0(10)1	0(10)0	0(10)1	0(10)1	
	6	0(10)0	0(10)0	0(6)0	0(10)0	0(10)0	
61	1	0(10)0	0(10)4	0(10)1	0(10)0	0(10)5	10
	2	0(10)0	0(10)0	0(5)0	0(10)0	0(10)0	9
	3	0(10)0	0(6+)0	0(6)0	0(5)0	0(6)0	Missing
	4	0(10)0	0(10)0	0(10)0	0(10)0	0(10)0	6
	5	0(5)0	0(9)0	0(6+)0	0(9)0	0(9)0	9
	6	0(10)0	0(10)0	0(10)0	0(10)0	0(10)0	3

Table 6 (Site C continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
62	1		10				
	2		10				
	3		10				
	4		10				
	5		10				
	6		7				
63	1		10				
	2		10				
	3		10				
	4		10				
	5		10				
	6		10				
64	1		10				
	2		10				
	3		10				
	4		5				
	5		10				
	6		7				
65	1		10				
	2		10				
	3		10				
	4		10				
	5		10				
	6		10				
66	1		10				10
	2		10				Missing
	3		10				Missing
	4		10				Missing
	5		10				Missing
	6		10				Missing
67	1		10				
	2		10				
	3		Not Recovered				
	4		10				
	5		Not Recovered				
68	1		10				
	2		10				
	3		Not Recovered				
	4		10				
	5		Not Recovered				

Table 6 (Site C continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
69	1		10				
	2		10				
	3	Not Recovered					
	4		10				
	5		10				
70	1		10				
	2		10				
	3		10				
	4		10				
	5		10				
73	1	9(10)	2(10)	9(10)	9(10)	5(10)	
	2	2(10)	2(10)	8(10)	8(10)	8(10)	
	3	4(10)	2(10)	8(10)	8(10)	8(10)	
	4	0(2)	0(3)	7(9)	0(7)	0(7)	
	7	0(0)	0(0)	4(0)	4(0)	4(0)	
74	1	1(10)	1(8)	9(10)	3(10)	2(10)	10
	2	0(0)	0(3)	9(10)	8(8)	8(10)	Missing
	3	0(10)	4(10)	9(10)	3(10)	2(10)	10
	4	0(0)	0(0)	8(0)	0(0)	0(0)	9
	7	Destroyed					7
75	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	8(10)	8(10)	8(10)	8(10)	8(10)	
	3	10(10)	10(10)	10(10)	9(10)	10(10)	
	4	8(10)	8(10)	10(10)	10(10)	10(10)	
	7	7(10)	7(10)	10(10)	10(10)	10(10)	
76	1	2(10)	2(10)	10(10)	8(10)	6(10)	10
	2	5(10)	4(10)	10(10)	5(10)	5(10)	10
	3	4(10)	4(10)	10(10)	7(10)	5(10)	10
	4	0(10)	2(5)	10(10)	2(10)	4(10)	9
	7	0(0)	0(0)	5(0)	0(0)	0(0)	7
77	1	6(10)	10(10)	10(10)	10(10)	10(10)	
	2	5(10)	4(10)	10(10)	8(10)	8(10)	
	3	3(10)	3(10)	10(10)	8(10)	5(10)	
	4	3(10)	3(10)	6+(10)	7(10)	3(10)	
	7	0(0)	1(1)	6+(0)	0(0)	1(0)	
78	1	2(10)	2(10)	10(10)	9(10)	10(10)	10
	2	0(8)	0(4)	8(10)	1(10)	0(10)	10
	3	0(0)	0(0)	8(4)	3(5)	1(5)	9
	4	0(0)	0(0)	7(0)	0(0)	0(0)	9
	7	Destroyed					Missing

Table 6 (Site C continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
79	1	Not Recovered					
	2	5(10)	4(10)	10(10)	8(10)	8(10)	
	3	3(10)	5(10)	9(10)	8(10)	8(10)	
	4	4(10)	2(3)	7(10)	6+(10)	7(10)	
	7	Destroyed					
80	1	2(5)	2(2)	10(10)	10(10)	10(10)	9
	2	0(0)	0(0)	8(8)	8(1)	8(3)	10
	3	0(0)	0(0)	6+(0)	5(0)	5(1)	9
	4	0(0)	0(0)	7(0)	5(0)	7(0)	9
	7	Destroyed					
81	1	9(10)	6+(10)	10(10)	10(10)	10(10)	
	2	Not Recovered					
	3	4(10)	2(10)	6+(10)	7(10)	8(10)	
	4	4(10)	3(10)	7(10)	7(10)	7(10)	
	7	0(0)	0(0)	6+(5)	4(1)	3(1)	
82	1	2(10)	1(5)	10(10)	9(10)	10(10)	Missing
	2	0(0)	0(1)	9(10)	2(8)	4(8)	10
	3	0(0)	0(0)	9(0)	2(0)	2(2)	9
	4	0(0)	0(0)	8(0)	0(0)	0(0)	9
	7	Destroyed					Missing
83	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	10(10)	6(10)	10(10)	10(10)	10(10)	
	3	2(7)	5(10)	10(10)	5(10)	9(10)	
	4	Not Recovered					
	7	0(0)	0(0)	7(0)	5(0)	5(0)	
84	1	6(10)	6(10)	10(10)	10(10)	10(10)	10
	2	5(10)	5(10)	10(10)	10(10)	10(10)	10
	3	2(7)	4(10)	10(10)	4(7)	10(10)	10
	4	3(3)	2(5)	10(5)	4(9)	3(5)	9
	7	Destroyed					
85	1	6+(10)	5(10)	9(10)	9(10)	9(10)	
	2	6(10)	4(10)	10(10)	8(10)	9(10)	
	3	4(9)	5(9)	10(10)	8(10)	8(10)	
	4	0(6)	1(0)	8(4)	6(5)	5(10)	
	7	Destroyed					
86	1	0(9)	1(0)	9(9)	9(9)	9(9)	Missing
	2	1(0)	0(0)	10(0)	8(0)	10(0)	Missing
	3	0(0)	1(0)	8(1)	5(4)	3(0)	10
	4	0(0)	0(0)	6(0)	0(0)	5(0)	9
	7	Destroyed					Missing

Table 6 (Site C continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
87	1	6(10)	5(10)	9(10)	8(10)	8(10)	
	2	4(10)	3(10)	8(10)	8(10)	8(10)	
	3	5(10)	2(10)	8(10)	8(10)	8(10)	
	4	2(10)	4(10)	8(10)	7(10)	5(10)	
	7	0(0)	0(0)	0(10)	0(0)	0(0)	
88	1	2(5)	1(10)	9(10)	0(10)	9(10)	10
	2	1(0)	1(5)	8(10)	8(1)	8(10)	10
	3	0(0)	0(0)	7(0)	7(0)	8(0)	9
	4	Destroyed					9
	7	Destroyed					Missing
89	1	9	9	9	9	9	
	2	8	8	9	9	9	
	3	8	8	9	9	8	
90	1	9	9	9	9	9	10
	2	8	8	9	9	9	Missing
	3	7	8	9	8	8	Missing
91	1	0(0)	0(0)	6(6)	6(6)	5(5)	
	2	1(1)	1(4)	5(5)	7(4)	7(5)	
	3	Destroyed					
93	1	5(5)	5(5)	6(6)	5(5)	5(5)	
	2	7(7)	6(6)	8(7)	8(7)	8(7)	
	3	Not Recovered					
95	1	8	8	8	9	9	
	4	7	7	7	7	7	
96	1	0	0	7	5	0	9
	4	Destroyed					7
97	1	8	8	10	10	10	
	4	8	8	8	8	8	
98	1	0	0	10	5	4	9
	4	0	0	7	0	0	8
99	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	4	8(10)	8(10)	10(10)	10(10)	10(10)	
100	1	3(10)	5(10)	10(10)	10(10)	10(10)	9
	4	2(5)	0(5)	10(5)	10(5)	7(5)	9
101	1	6(10)	7(10)	10(10)	9(10)	8(10)	
	4	7(10)	7(10)	10(10)	7(10)	7(10)	

Table 6 (Site C continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
102	1	2(10)	1(10)	9(10)	7(10)	5(10)	9
	4	0(10)	0(10)	5(10)	0(10)	0(10)	9
103	1	6(10)	6(10)	10(10)	10(10)	10(10)	
	4	5(0)	1(0)	7(10)	5(4)	5(4)	
104	1	7(10)	6+(10)	10(10)	10(10)	10(10)	
	4	0(0)	0(0)	4(0)	4(0)	4(0)	
105	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	4	2(0)	6+(6)	6+(10)	4(2)	6+(10)	

Table 7. Performance of Shields in Cable Specimens Buried Up to Seven Years in Lakewood Sand (Site D)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
56	1			10			
	2	10	10	10	10	10	
	3	10	10	10	10	10	
	4	10	10	10	10	10	
	5	10	10	10	10	10	
	6	Not Recovered					
57	1	Not Recovered					
	2	10(5)	10(5)	10	10(5)	10	10
	3	10(0)	10(4)	10	10(5)	10(5)	Missing
	4	10(6)	10(5)	10	10	10	10
	5	10(0)	10(4)	10(5)	10(4)	10(4)	10
	6	Not Recovered					
62	1			10			
	2			10			
	3			10			
	4			8			
	5			10			
	6			10			
63	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
	6			10			
64	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
	6			10			
65	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
	6			10			
66	1			10			Missing
	2			10			Missing
	3			10			Missing
	4			10			Missing
	5			10			10
	6			10			Missing

Table 7 (Site D continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Rindow	1/2 Inch Ring	Copper Cathode
67	1			10			
	2	Not Recovered					
	3			10			
	4			10			
	5			10			
68	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
69	1	Not Recovered					
	2			10			
	3	Not Recovered					
	4			10			
	5	Not Recovered					
70	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
73	1	9(10)	6(10)	10(10)	9(10)	9(10)	
	2	8(10)	4(10)	9(10)	8(10)	8(10)	
	3	8(10)	3(10)	8(10)	8(10)	8(10)	
	4	5(10)	3(10)	7(10)	7(10)	5(10)	
	7	2(10)	1(10)	7(10)	7(10)	7(10)	
74	1	5(10)	2(10)	9(10)	9(10)	4(10)	10
	2	4(10)	4(10)	8(10)	8(10)	8(10)	10
	3	4(10)	2(10)	8(10)	8(10)	8(10)	10
	4	3(10)	2(5)	7(10)	7(10)	4(10)	9
	7	0(7)	0(7)	5(8)	5(7)	7(7)	7
75	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
	3	10(10)	10(10)	10(10)	10(10)	10(10)	
	4	10(10)	10(10)	10(10)	10(10)	10(10)	
	7	7(10)	6+(10)	10(10)	10(10)	10(10)	
76	1	10(10)	6+(10)	10(10)	10(10)	10(10	10
	2	5(10)	6(10)	10(10)	10(10)	10(10)	10
	3	6+(10)	6+(10)	10(10)	10(10)	10(10)	10
	4	8(10)	5(10)	10(10)	10(10)	10(10)	9
	7	5(10)	5(9)	10(10)	10(10)	6+(10)	7

Table 7 (Site D continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
77	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	8(10)	6(10)	10(10)	9(10)	9(10)	
	3	9(10)	9(10)	10(10)	9(10)	9(10)	
	4	9(10)	3(10)	9(10)	6+(10)	6(10)	
	7	5(10)	1(10)	8(10)	8(10)	6+(10)	
78	1	6(10)	5(10)	10(10)	10(10)	10(10)	10
	2	5(10)	4(10)	10(10)	5(10)	10(10)	10
	3	4(10)	2(10)	10(10)	9(10)	7(10)	10
	4	2(10)	2(10)	9(10)	7(10)	9(10)	10
	7	1(7)	2(7)	7(10)	7(10)	8(7)	7
79	1	6+(10)	6(10)	10(10)	10(10)	10(10)	
	2	8(10)	5(10)	10(10)	9(10)	9(10)	
	3	8(10)	8(10)	10(10)	9(10)	9(10)	
	4	4(10)	2(10)	9(10)	9(10)	9(10)	
	7	1(10)	1(10)	8(10)	8(10)	8(10)	
80	1	8(10)	6(10)	10(10)	10(10)	10(10)	10
	2	5(10)	4(10)	10(10)	8(10)	8(10)	10
	3	3(10)	2(10)	9(10)	9(10)	8(10)	10
	4	1(7)	1(7)	8(8)	6+(8)	7(8)	10
	7	1(6)	1(1)	7(5)	7(6)	7(6)	7
81	1	9(10)	9(10)	10(10)	10(10)	10(10)	
	2	8(10)	5(10)	10(10)	10(10)	10(10)	
	3	5(10)	4(10)	10(10)	9(10)	9(10)	
	4	5(10)	4(10)	9(10)	8(10)	8(10)	
	7	2(10)	1(10)	7(10)	7(10)	8(10)	
82	1	5(10)	5(10)	10(10)	10(10)	10(10)	10
	2	4(10)	2(10)	9(10)	9(10)	9(10)	10
	3	4(10)	2(10)	9(10)	8(10)	9(10)	10
	4	2(10)	2(10)	9(10)	6+(10)	8(10)	10
	7	0(1)	0(0)	1(7)	1(1)	1(0)	7
83	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
	3	10(10)	10(10)	10(10)	10(10)	10(10)	
	4	10(10)	10(10)	10(10)	10(10)	10(10)	
	7	7(10)	8(10)	8(10)	7(10)	10(10)	
84	1	10(10)	6(10)	10(10)	10(10)	10(10)	10
	2	5(10)	5(10)	10(10)	10(10)	10(10)	10
	3	6(10)	6(10)	10(10)	10(10)	10(10)	10
	4	6+(10)	5(10)	10(10)	10(10)	10(10)	10
	7	0(0)	3(7)	10(7)	10(0)	7(7)	7

Table 7 (Site D continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
85	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	7(10)	5(10)	10(10)	10(10)	10(10)	
	3	5(10)	5(10)	10(10)	9(10)	10(10)	
	4	4(10)	2(10)	8(10)	9(10)	6(10)	
	7	2(8)	1(8)	7(9)	7(9)	8(9)	
86	1	5(10)	5(10)	10(10)	10(10)	10(10)	10
	2	4(10)	4(10)	10(10)	8(10)	10(10)	10
	3	2(9)	2(6+)	9(6+)	8(9)	9(8)	10
	4	1(6+)	1(6)	6+(8)	7(7)	7(7)	10
	7	Destroyed					7
87	1	7(10)	7(10)	9(10)	7(10)	8(10)	
	2	5(10)	5(10)	5(10)	8(10)	8(10)	
	3	5(10)	5(10)	8(10)	8(10)	8(10)	
	4	2(10)	2(10)	8(10)	7(10)	7(10)	
	7	1(10)	1(10)	7(10)	7(10)	7(10)	
88	1	6(10)	5(10)	8(10)	8(10)	8(10)	10
	2	2(10)	3(10)	8(10)	9(10)	8(10)	10
	3	2(10)	2(10)	7(10)	8(10)	8(10)	9
	4	2(4)	2(7)	7(10)	7(10)	7(10)	9
	7	1(5)	1(1)	7(5)	2(5)	7(4)	7
89	1	10	9	9	10	10	
	2	9	9	9	9	9	
	3	9	9	9	9	9	
90	1	9	9	9	9	10	10
	2	9	9	9	9	9	10
	3	9	9	9	9	9	10
91	1	6(9)	6(9)	9(9)	9(9)	9(9)	
	2	1(1)	0(0)	5(5)	6(6)	6(6)	
	3	0(1)	0(3)	5(5)	5(5)	5(5)	
93	1	9(7)	9(7)	9(7)	9(7)	9(9)	
	2	8(7)	6+(6+)	8(6)	8(7)	8(7)	
	3	5(5)	6(6)	6(4)	8(3)	8(3)	
95	1	9	9	10	10	10	
	2	10	10	10	10	10	
	5	8	9	9	10	10	
96	1	-	4	9	-	7	Missing
	2	5	5	7	5	9	10
	5	5	6	7	7	7	7

Table 7 (Site D continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
97	1	10	10	10	10	10	
	2	10	10	10	10	10	
	5	10	10	10	10	10	
98	1	8	8	10	10	10	10
	2	5	5	10	5	8	10
	5	7	7	8	8	8	7
99	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	5(10)	6(10)	10(10)	10(10)	10(10)	
	5	7(10)	6(10)	10(10)	10(10)	10(10)	
100	1	10(10)	10(10)	10(10)	10(10)	10(10)	10
	2	3(10)	5(10)	10(10)	10(10)	10(10)	10
	5	5(10)	5(10)	10(10)	10(10)	7(10)	7
101	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	6(10)	6(10)	9(10)	9(10)	9(10)	
	5	8(10)	8(10)	10(10)	10(10)	10(10)	
102	1	10(10)	10(10)	9(10)	9(10)	9(10)	10
	2	Not Recovered					
	5	2(10)	2(10)	8(10)	8(10)	2(10)	7
103	1	10	10	10	10	10	
	2	10(10)	10(10)	10(10)	9(10)	10(10)	
	5	7(10)	8(10)	10(10)	10(10)	10(10)	
104	1	10	10	10	10	10	
	2	9(10)	9(10)	10(10)	9(10)	9(10)	
	5	7(8)	8(8)	8(8)	8(8)	8(8)	
105	1	10	10	10	10	10	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
	5	10(10)	10(10)	10(10)	10(10)	10(10)	

Table 8. Performance of Shields in Cable Specimens Buried Up to Six Years in Coastal Sand (Site E)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Cooper Cathode
56	1	10	10	10	10	10	
	2	10	10	10	10	10	
	3	10(5)	10(5)	10(7)	10(5)	10(6)	
	4	10(2)	10	10	10(5)	10	
	5	Not Recovered					
	6	10(5)	10(3)	10(5)	10(5)	10(5)	
57	1	10(4)	10(4)	10(5)	10(5)	10(5)	9
	2	10(0)	10(5)	10	10(5)	10(5)	10
	3	10(0)	10(4)	10(5)	10(4)	10(4)	Missing
	4	10(4)	10(4)	10(4)	10(4)	10(4)	10
	5	Not Recovered					
	6	10(0)	10(0)	10(0)	10(0)	10(0)	9
58	1	10(7)	10(7)	10(7)	10(7)	10(7)	
	2	10(4)	10(4)	10(2)	10(7)	10(7)	
	3	10(4)	10(4)	10(5)	10(5)	10(5)	
	4	10(1)	10(0)	10(1)	10(4)	10(5)	
	5	10(5)	10(5)	10(0)	10(1)	10(3)	
59	1	10(1)	10(2)	10(7)	10(0)	10(7)	10
	2	10(0)	10(0)	10(0)	10(0)	10(0)	9
	3	10(0)	10(0)	6(0)	9(0)	9(0)	9
	4	10(0)	10(0)	10(0)	10(0)	10(0)	9
	5	10(0)	10(0)	5(0)	5(0)	10(0)	9
	6	10(0)	10(0)	10(0)	10(0)	10(0)	9
60	1	2(10)7	2(10)7	8(10)7	4(10)8	5(10)8	
	2	0(10)5	0(10)1	0(10)2	2(10)5	5(10)4	
	3	0(10)5	4(10)7	0(10)4	4(10)5	5(10)8	
	4	0(10)5	0(10)4	3(10)0	0(10)5	2(10)5	
	5	Not Recovered					
61	1	0(10)0	0(10)0	0(10)0	0(10)0	0(10)0	10
	2	0(10)1	0(10)0	0(10)0	0(10)0	0(10)0	Missing
	3	0(10)0	0(10)0	0(10)0	0(10)0	0(10)0	10
	4	0(10)0	0(10)0	0(6)0	0(10)0	0(10)0	Missing
	5	0(10)0	0(10)0	0(10)0	0(10)0	0(10)0	10
	6	0(10)0	0(10)0	0(6)0	0(6)0	0(9)0	10
62	1			10			
	2			10			
	3			10			
	4			8			
	5			10			
	6			Not recovered			

Table 8 (Site E continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
63	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
	6			10			
64	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
	6			10			
65	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
	6			10			
66	1			10			10
	2			10			Missing
	3			10			10
	4			10			Missing
	5			10			10
	6			10			Missing
73	1	9(10)	9(10)	9(10)	9(10)	9(10)	
	2	0(10)	5(10)	9(10)	9(10)	9(10)	
	3	9(10)	8(10)	8(10)	9(10)	9(10)	
	4	3(10)	3(10)	6+(10)	7(10)	7(10)	
74	1	5(10)	2(10)	9(10)	9(10)	9(10)	10
	2	4(10)	3(10)	8(10)	8(10)	8(10)	10
	3	3(10)	2(10)	9(10)	8(10)	8(10)	10
	4	0(3)	0(10)	7(10)	7(10)	3(10)	10
75	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	9(10)	9(10)	10(10)	10(10)	10(10)	
	3	10(10)	10(10)	10(10)	10(10)	10(10)	
	4	9(10)	10(10)	10(10)	10(10)	10(10)	
76	1	5(10)	4(10)	10(10)	2(10)	5(10)	10
	2	10(10)	6(10)	10(10)	10(10)	10(10)	10
	3	5(10)	3(10)	10(10)	5(10)	5(10)	10
	4	4(10)	4(10)	10(10)	5(10)	4(10)	9

Table 8 (Site E continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
77	1	6(10)	6(10)	10(10)	10(10)	10(10)	
	2	10(10)	6(10)	10(10)	9(10)	8(10)	
	3	5(10)	6(10)	10(10)	8(10)	6(10)	
	4	3(10)	3(5)	5(10)	6+(10)	5(10)	
78	1	3(10)	2(10)	10(10)	9(10)	10(4)	Missing
	2	0(10)	2(10)	9(10)	9(10)	8(10)	10
	3	2(10)	2(10)	10(10)	5(10)	8(10)	10
	4	0(10)	0(2)	8(10)	6(4)	6(3)	9
79	1	9(10)	9(10)	6+(10)	6+(10)	9(10)	
	2	5(10)	6(10)	10(10)	9(10)	10(10)	
	3	5(10)	5(10)	9(10)	8(10)	6+(10)	
	4	Not Recovered					
80	1	4(10)	4(10)	10(10)	10(10)	10(10)	10
	2	2(10)	2(10)	10(10)	9(10)	10(10)	10
	3	4(10)	3(10)	6+(10)	8(10)	8(10)	10
	4	2(4)	0(0)	7(5)	7(6)	7(5)	10
81	1	5(10)	9(10)	9(10)	10(10)	9(10)	
	2	4(10)	5(10)	10(10)	10(10)	10(10)	
	3	5(10)	5(10)	8(10)	8(10)	6+(10)	
	4	5(10)	5(10)	8(10)	9(10)	9(10)	
82	1	3(10)	3(10)	9(10)	10(10)	9(10)	10
	2	2(10)	3(10)	8(10)	9(10)	8(10)	10
	3	4(10)	2(10)	8(10)	8(10)	8(10)	10
	4	5(5)	2(4)	8(10)	7(7)	7(6)	10
83	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
	3	10(10)	10(10)	10(10)	10(10)	10(10)	
	4	9(10)	9(10)	10(10)	9(10)	9(10)	
84	1	10(10)	6(10)	10(10)	4(10)	9(10)	10
	2	7(10)	5(10)	10(10)	10(10)	10(10)	10
	3	7(5)	6(10)	10(10)	10(10)	7(10)	10
	4	6+(5)	5(5)	10(7)	6(7)	6(7)	10
85	1	9(10)	6(10)	10(10)	10(10)	10(10)	
	2	5(10)	7(10)	10(10)	9(10)	9(10)	
	3	Not Recovered					
	4	6(8)	4(7)	9(8)	7(8)	8(8)	
86	1	5(9)	4(4)	10(9)	9(9)	10(9)	10
	2	4(5)	5(1)	10(5)	8(5)	10(3)	10
	3	2(6+)	2(4)	8(6)	8(6)	9(6)	10
	4	4(3)	3(6)	8(5)	8(5)	9(6)	10

Table 8 (Site E continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
87	1	7(10)	7(10)	6(10)	9(10)	9(10)	
	2	8(10)	8(10)	8(10)	8(10)	8(10)	
	3	6(10)	7(10)	8(10)	8(10)	8(10)	
	4	5(10)	6(10)	7(10)	7(10)	7(10)	
88	1	5(10)	3(10)	9(10)	8(10)	8(10)	10
	2	4(10)	2(10)	8(10)	8(10)	8(10)	10
	3	3(10)	2(10)	7(10)	8(10)	8(10)	8
	4	1(10)	1(10)	8(10)	7(10)	8(10)	10
89	1	9	9	9	9	9	
	2	9	9	9	9	9	
	3	9	9	9	9	9	
90	1	9	9	9	9	9	10
	2	9	9	9	9	9	Missing
	3	9	9	9	9	9	9
91	1	2(2)	0(0)	5(5)	6(6)	6(6)	
	2	1(1)	1(1)	5(5)	5(5)	5(5)	
	3	Destroyed					
93	1	8(7)	7(7)	8(7)	6(6)	8(7)	
	2	6(6)	6(6)	8(7)	6+(6+)	6(6)	
	3	7(1)	5(1)	6(1)	6+(2)	7(2)	
95	1	10	10	10	10	10	
	2	10	10	10	10	10	
96	1	6+	5	8	7	7	10
	2	3	3	7	6	6	9
97	1	10	10	10	10	10	
	2	10	10	10	10	10	
98	1	6	6+	10	10	10	10
	2	0	0	9	5	6+	9
99	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	
100	1	6(10)	6+(10)	10(10)	10(10)	10(10)	10
	2	6(10)	7(10)	10(10)	10(10)	10(10)	10
101	1	Not Recovered					
	2	6(10)	5(10)	10(10)	10(10)	10(10)	

Table 8 (Site E continued)

Systems	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
102	1	7(10)	5(10)	8(10)	8(10)	8(10)	10
	2	3(10)	4(10)	10(10)	9(10)	9(10)	10
103	1	9	9	10	9	9	
	2	8(10)	8(10)	8(10)	8(10)	8(10)	
104	1	8	9	9	9	9	
	2	9(8)	9(8)	8(9)	8(9)	8(8)	
105	1	10	10	10	10	10	
	2	10(10)	10(10)	10(10)	10(10)	10(10)	

Table 9. Performance of Shields in Cable Specimens Buried Up to Seven Years in Tidal Marsh (Site G)

Systems	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
56	1	10	10	10	10	10	
	2	0	10(2)	10(0)	10(0)	10(5)	
	3	10(5)	10(2)	10(5)	10(5)	10(5)	
	4	0(0)	1(0)	10(0)	10(0)	10(0)	
	5	10(0)	10(1)	10(0)	10(0)	10(0)	
	6	0(0)	10(1)	10(0)	5(0)	10(1)	
57	1	9(2)	9(3)	10(5)	9(3)	9(3)	9
	2	0	5(0)	5(0)	4(5)	10(0)	9
	3	0	9(4)	9(5)	5	10(3)	Missing
	4	0	0(4)	0	0	0	Missing
	5	0(0)	2(2)	10(0)	10(2)	10(2)	Missing
	6	0(0)	0(0)	5(0)	3(0)	3(0)	3
58	1	6(0)	6(0)	5(0)	5(0)	6(0)	
	2	9(0)	5(0)	5(0)	6+(0)	5(0)	
	3	9(0)	9(0)	5(0)	6(0)	6+(0)	
	4	6(0)	5(0)	5(0)	5(0)	5(0)	
	5	6(0)	9(0)	8(0)	9(0)	9(0)	
	6	5(0)	6+(0)	6+(0)	6(0)	9(0)	
59	1	9(0)	6+(1)	9(0)	6(0)	10(1)	9
	2	6(0)	6(0)	5(0)	5(0)	6(0)	9
	3	5(0)	9(0)	5(0)	6(0)	6(0)	9
	4	2(0)	6(0)	5(0)	6(0)	0(0)	9
	5	6(0)	5(0)	6(0)	6(0)	6(0)	9
	6	6(0)	4(0)	5(0)	5(0)	5(0)	9
60	1	0(6)0	2(8)5	1(5)0	0(6)0	1(6+)7	
	2	0(10)0	0(6)0	0(5)0	0(9)0	0(6)0	
	3	0(8)0	0(9)0	0(6)0	0(6)0	0(8)0	
	4	0(9)0	0(8)0	0(5)0	0(9)0	0(8)0	
	5	Not Recovered					
	6	0(5)0	0(9)0	0(5)0	0(6)0	0(9)0	
61	1	0(5)0	1(8)4	0(5)3	0(5)0	0(6+)0	9
	2	0(5)0	0(6+)0	0(5)0	0(9)0	0(9)0	9
	3	0(6+)0	0(6+)0	0(6)0	0(6)0	0(9)0	9
	4	0(4)0	0(6)0	0(5)0	0(8)0	0(9)0	9
	5	0(4)0	0(8)0	0(6+)0	0(9)0	0(6)0	9
	6	0(6)0	0(8)0	0(5)0	0(6)0	0(5)0	9

Table 9 (Site G continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
62	1			6+			
	2			5			
	3			10			
	4			5			
	5			10			
	6			7			
63	1			10			
	2			5			
	3			10			
	4			5			
	5			5			
	6			10			
64	1			10			
	2			10			
	3			10			
	4			5			
	5			5			
	6			6			
65	1			10			
	2			10			
	3			10			
	4			10			
	5			10			
	6			10			
73	1	9(10)	9(10)	10(10)	9(10)	9(10)	
	2	0(10)	1(10)	9(10)	8(10)	8(10)	
	3	0(7)	0(0)	8(10)	0(10)	0(1)	
	4	0(0)	0(0)	7(10)	3(7)	0(5)	
	7	0(0)	0(0)	0(10)	0(0)	0(0)	
74	1	0(10)	1(5)	9(9)	9(9)	3(5)	10
	2	0(0)	0(0)	8(0)	2(0)	0(0)	10
	3	0(0)	0(0)	8(0)	2(0)	0(0)	9
	4	Destroyed					9
	7	Destroyed					Missing
75	1	10(10)	10(10)	10(10)	10(10)	10(10)	
	2	1(10)	5(10)	10(10)	5(10)	5(10)	
	3	5(10)	1(10)	10(10)	8(10)	2(10)	
	4	2(10)	5(10)	10(10)	4(10)	10(10)	
	7	0(6+)	0(9)	0(10)	0(10)	0(10)	

Table 9 (Site G continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
76	1	1(10)	10(10)	10(10)	10(10)	10(10)	10
	2	0(10)	0(10)	5(10)	0(10)	4(10)	10
	3	2(10)	0(10)	0(10)	4(10)	2(10)	10
	4	0(10)	0(10)	0(10)	0(10)	0(10)	9
	7	0(0)	0(0)	8(0)	0(0)	0(0)	Missing
77	1	4(10)	1(10)	10(10)	10(10)	10(10)	
	2	0(10)	0(10)	10(10)	3(10)	0(10)	
	3	0(0)	0(10)	9(10)	2(5)	0(10)	
	4	0(0)	0(0)	9(0)	0(7)	3(0)	
	7	Destroyed					
78	1	10(2)	10(0)	10(4)	9(0)	10(0)	10
	2	0(0)	0(0)	8(4)	8(0)	3(0)	10
	3	0(0)	0(0)	6(2)	1(0)	2(0)	9
	4	Destroyed					9
	7	Destroyed					Missing
79	1	5(10)	1(2)	9(10)	9(10)	9(10)	
	2	1(3)	2(3)	8(10)	8(10)	8(10)	
	3	0(0)	0(0)	8(0)	5(0)	8(1)	
	4	0(0)	0(0)	7(0)	7(0)	8(0)	
	7	0(0)	0(0)	1(0)	0(0)	0(0)	
80	1	0(0)	1(1)	10(10)	6(10)	10(10)	10
	2	Destroyed					10
	3	Destroyed					9
	4	Destroyed					9
	7	Destroyed					Missing
81	1	5(10)	5(10)	10(10)	10(10)	10(10)	
	2	4(10)	5(10)	10(10)	10(10)	10(10)	
	3	0(0)	0(0)	5(5)	4(2)	4(0)	
	4	1(0)	0(0)	7(3)	7(5)	2(3)	
	7	Destroyed					
82	1	1(10)	1(10)	9(10)	9(10)	9(10)	10
	2	Destroyed					10
	3	Destroyed					9
	4	Destroyed					Missing
	7	Destroyed					Missing
83	1	2(10)	5(10)	10(10)	10(10)	10(10)	
	2	5(3)	5(3)	10(10)	8(8)	4(8)	
	3	1(10)	5(10)	10(10)	5(10)	7(10)	
	4	2(0)	7(5)	10(5)	3(0)	10(7)	
	7	0(0)	3(0)	5(0)	5(0)	5(0)	

Table 9 (Site G continued)

System	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
84	1	7(10)	5(6)	10(10)	10(10)	10(10)	9
	2	0(10)	0(10)	9(10)	2(10)	2(10)	Missing
	3	0(0)	0(0)	10(0)	3(2)	3(0)	8
	4	0(0)	0(0)	9(0)	0(0)	0(0)	9
	7	0(0)	2(0)	5(0)	2(0)	2(0)	Missing
85	1	5(10)	4(1)	10(10)	10(10)	10(10)	
	2	Destroyed					
	3	Destroyed					
	4	Destroyed					
	7	Destroyed					
86	1	0(0)	0(1)	9(5)	9(3)	9(2)	10
	2	Destroyed					10
	3	Destroyed					9
	4	Destroyed					9
	7	Destroyed					Missing
87	1	6(10)	3(10)	8(10)	8(10)	8(10)	
	2	0(4)	0(3)	8(5)	8(5)	8(5)	
	3	Destroyed					
	4	Destroyed					
	7	Destroyed					
88	1	0(0)	0(0)	8(8)	8(4)	8(4)	9
	2	Destroyed					9
	3	Destroyed					9
	4	Destroyed					8
	7	Destroyed					Missing
89	1	9	9	9	9	9	
	2	9	9	9	9	9	
	3	5	3	7	6	6	
90	1	9	9	9	9	9	9
	2	9	9	9	9	9	9
	3	6	6+	7	6+	6+	5
91	1	Destroyed					
	2	Destroyed					
	3	Destroyed					
92	1	Destroyed					
	2	Destroyed					
	3	Destroyed					
95	1	0	0	7	3	7	
	2	6	6+	7	7	7	
	5	Destroyed					

Table 9 (Site G continued)

	Exposure Time (years)	Exposed Window	Exposed Ring	Under Jacket	1/2 Inch Window	1/2 Inch Ring	Copper Cathode
96	1	Destroyed					
	2	Destroyed					
	5	Destroyed					
97	1	1	3	10	10	10	
	2	4	0	10	6	2	
	5	0	0	4	7	7	
98	1	0	0	10	2	0	9
	2	Destroyed					9
	5	Destroyed					Missing
99	1	4(10)	6(10)	10(10)	10(10)	10(10)	
	2	3(10)	3(10)	10(10)	3(10)	3(10)	
	5	0(5)	3(5)	4(5)	4(5)	4(5)	
100	1	5(10)	5(10)	10(10)	10(10)	10(10)	9
	2	0(0)	3(4)	5(9)	3(1)	2(4)	9
	5	Destroyed					Missing
101	1	4(10)	5(10)	6(10)	6(10)	5(10)	
	2	0(10)	2(10)	5(10)	3(10)	4(10)	
	5	0(0)	2(2)	7(7)	0(0)	3(3)	
102	1	0(10)	4(10)	5(10)	4(10)	5(10)	9
	2	0(10)	0(10)	4(10)	0(10)	0(10)	9
	5	Destroyed					Missing

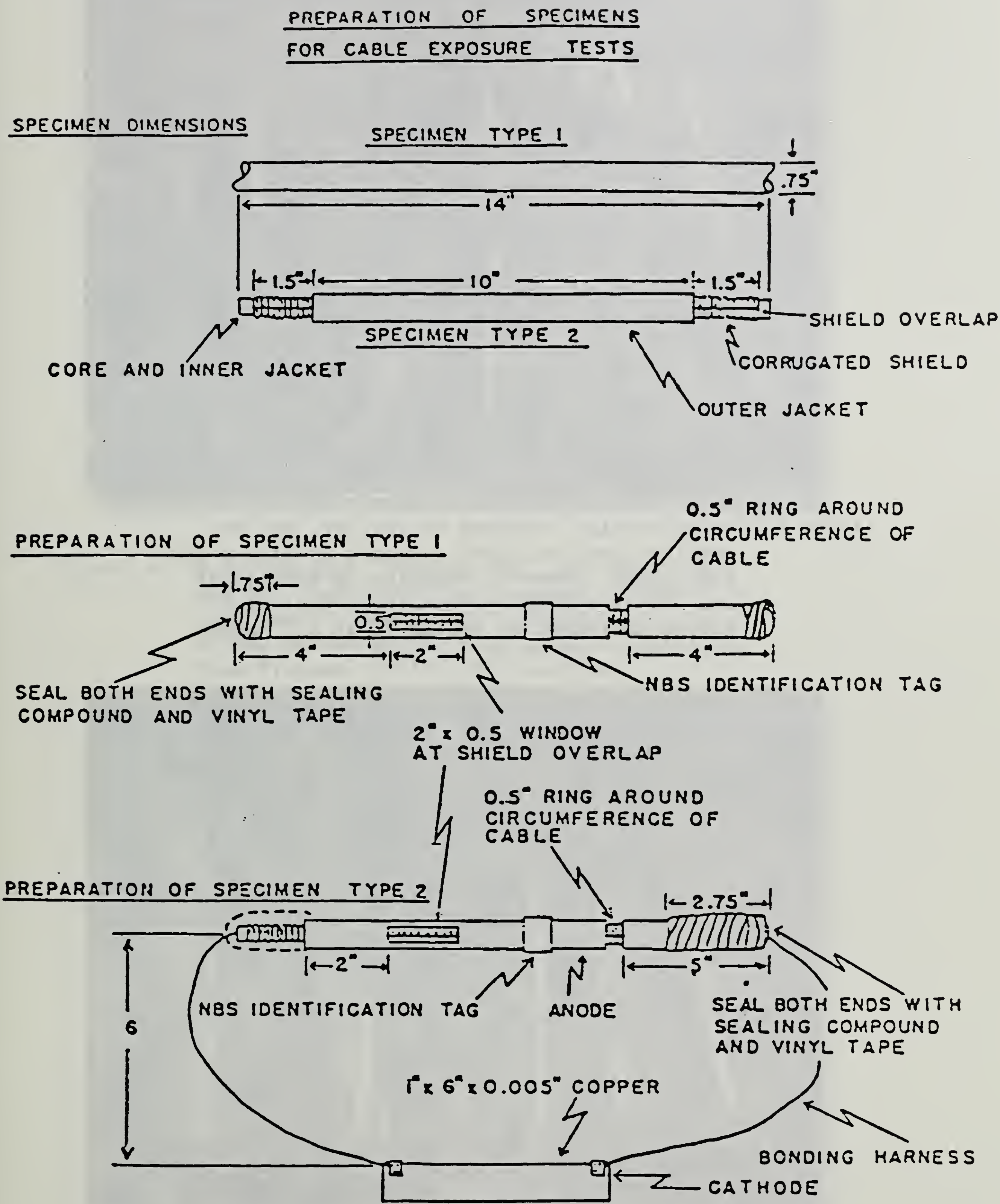

Figure 1 Preparation of specimens for cable exposure tests.

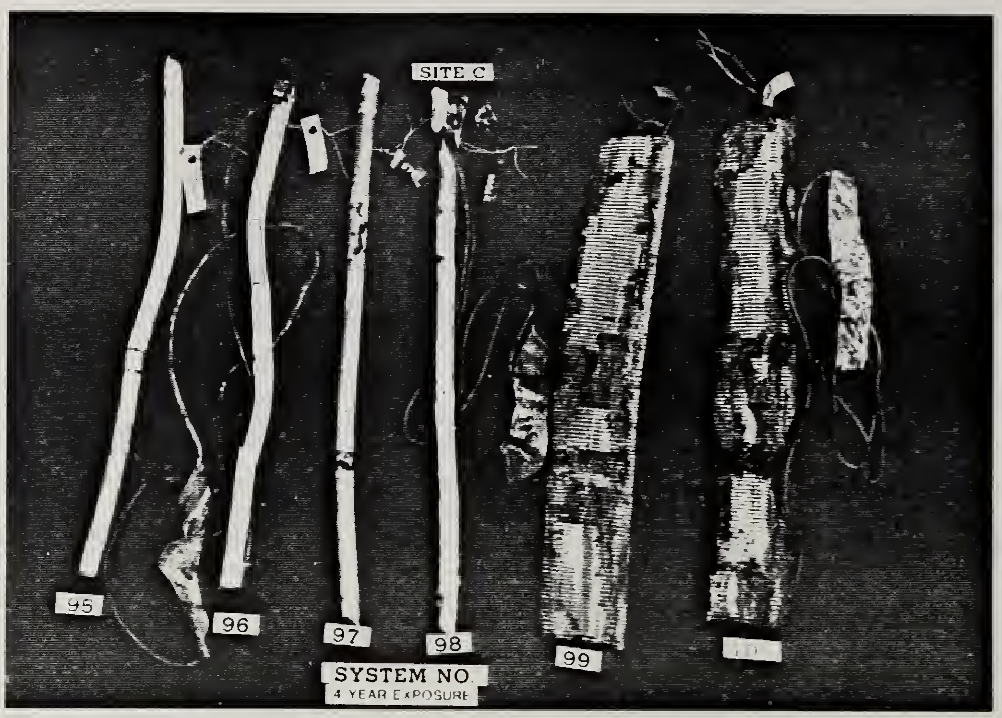

Figure 2. Outer Shield: Systems 95, 96, 97, 98, 99, and 100, left to right, exposed at Site C for four years. Severe corrosion on Systems 98 and 100 at window and/or ring areas, with severe corrosion on System 96 at all areas.

Figure 3. Outer Shield: Systems 95, 96, 97, and 98, Inner Shield: Systems 99 and 100, left to right, exposed at Site C for four years. Severe corrosion on System 98 at the window and ring areas, with severe corrosion on System 96 at all areas.

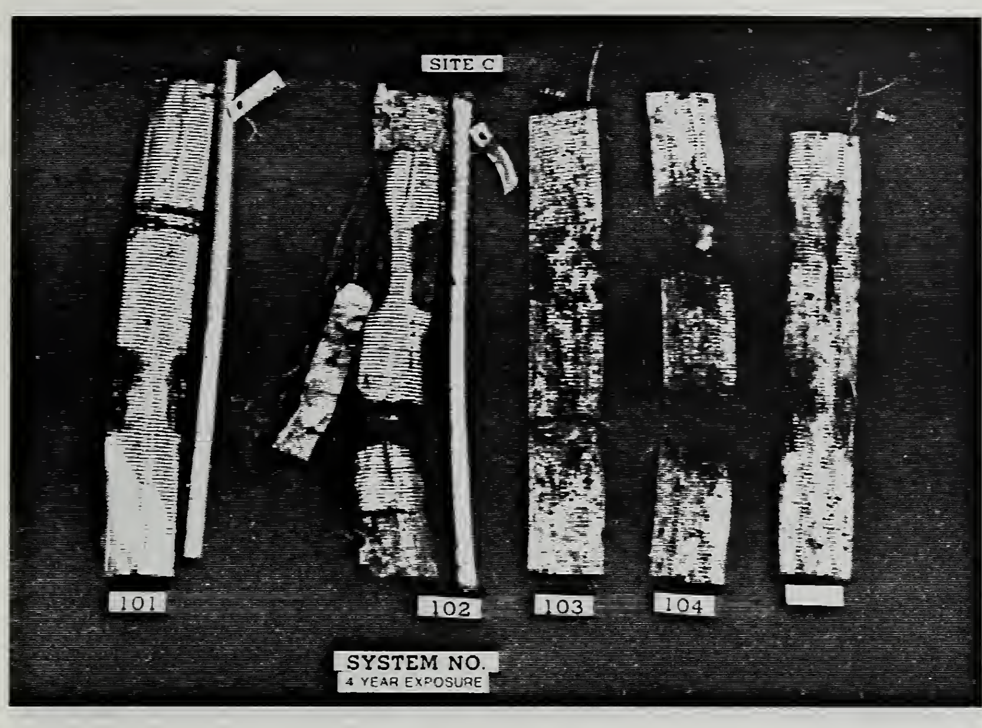

Figure 4. Outer Shield: Systems 101, 102, 103, 104, and 105, left to right, exposed at Site C for four years. Dark areas indicate corrosion at the window and/or ring areas on specimens from Systems 102,103,104, and 105.

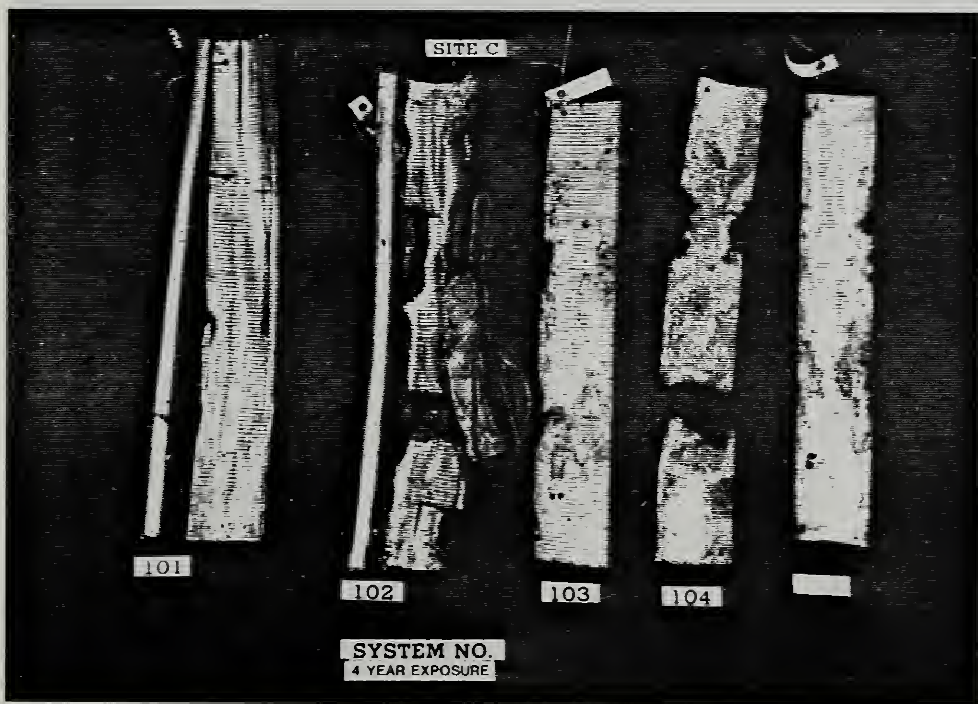

Figure 5. Inner Shield: Systems 101, 102, 103, 104, and 105, left to right, exposed at Site C for four years. Severe degradation at the window and/or ring areas on the specimens from Systems 103, 104, and 105.

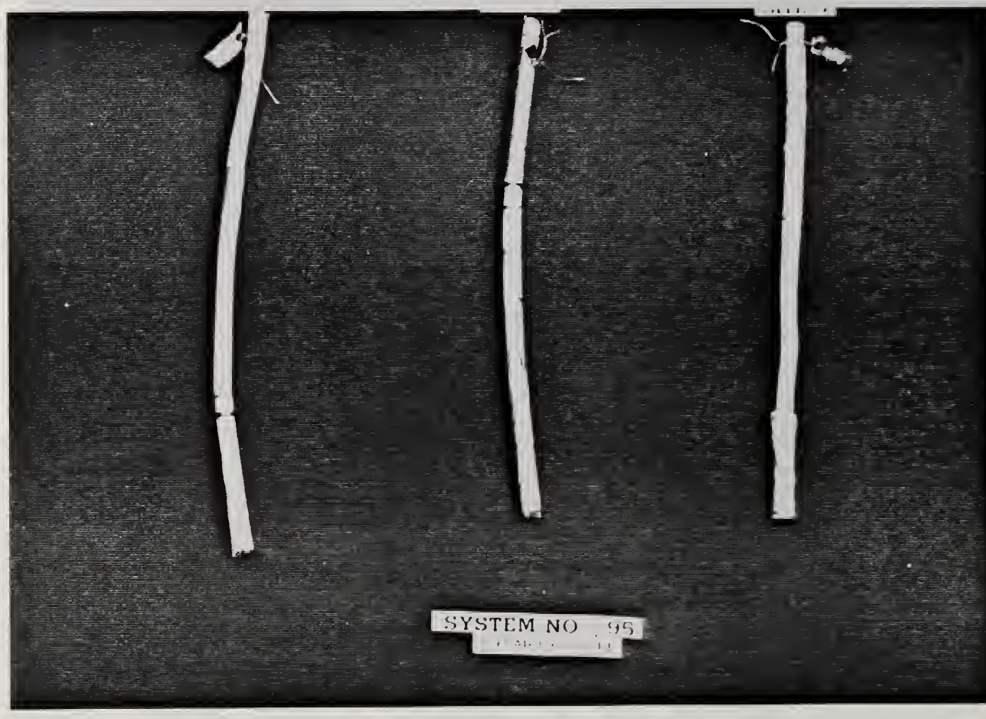

Figure 6. Outer Shield: System 95, Sites B, D, and G, left to right, exposed for five years. Severe degradation at all areas on the specimen from Site G.

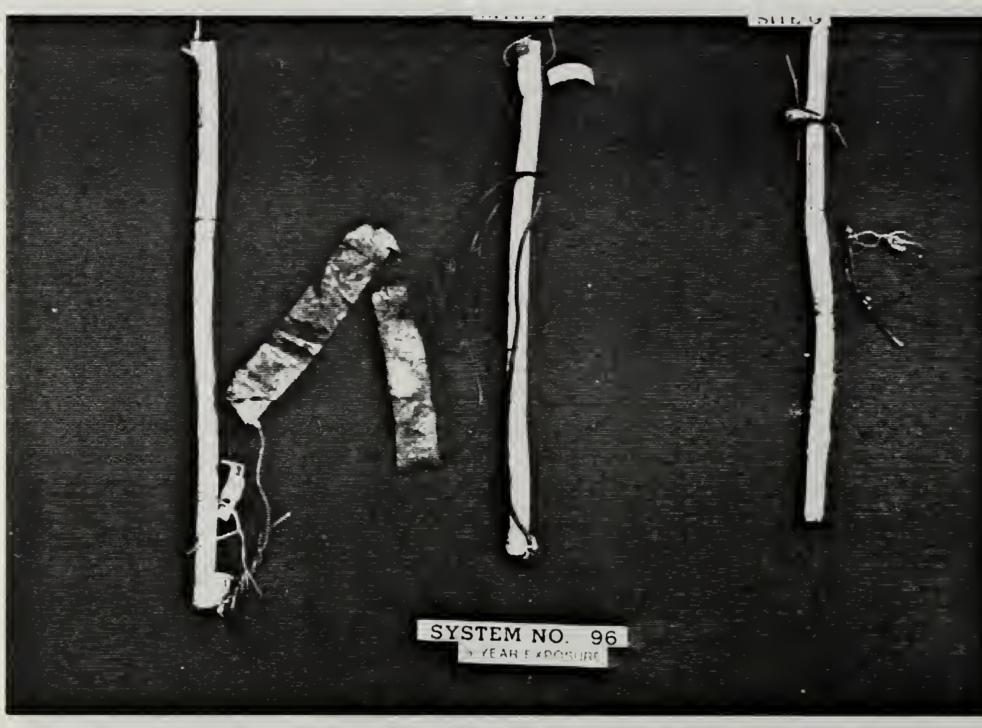

Figure 7. Outer Shield: System 96, Sites B, D, and G, left to right, exposed for five years. Coupling this system to copper accelerated corrosion on the specimens from all sites.

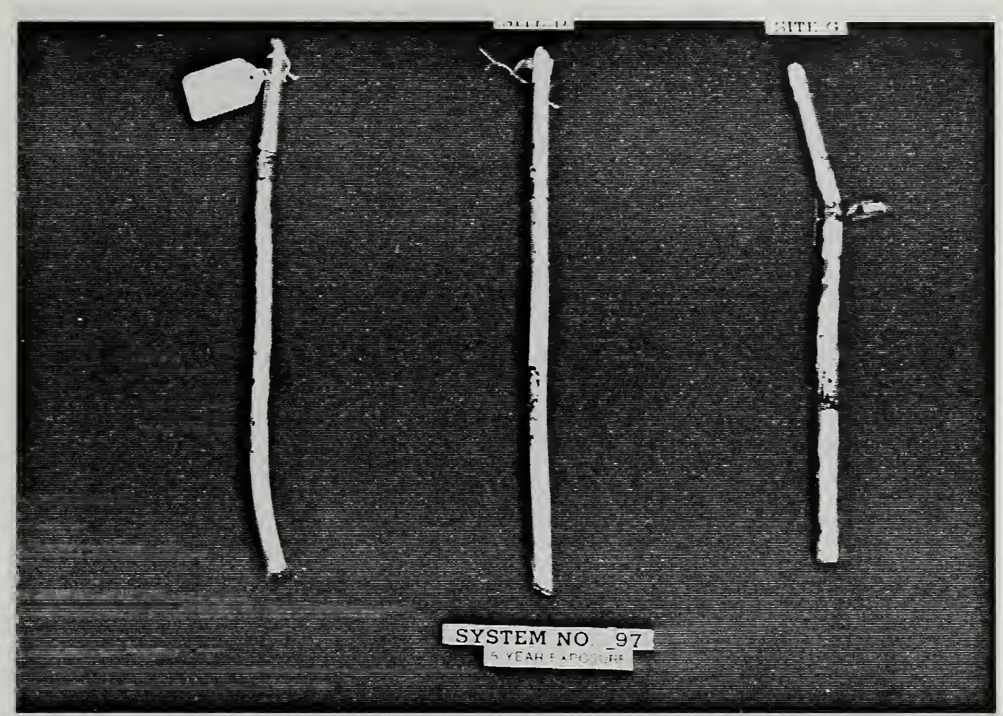

Figure 8. Outer Shield: System 97, Sites B, D, and G, left to right, exposed for five years. Degradation at the window and ring areas on the specimen from Site G was severe.

Figure 9. Outer Shield: System 98, Sites B, D, and G, left to right, exposed for five years. Coupling this system to copper accelerated degradation at all areas on specimens from all sites.

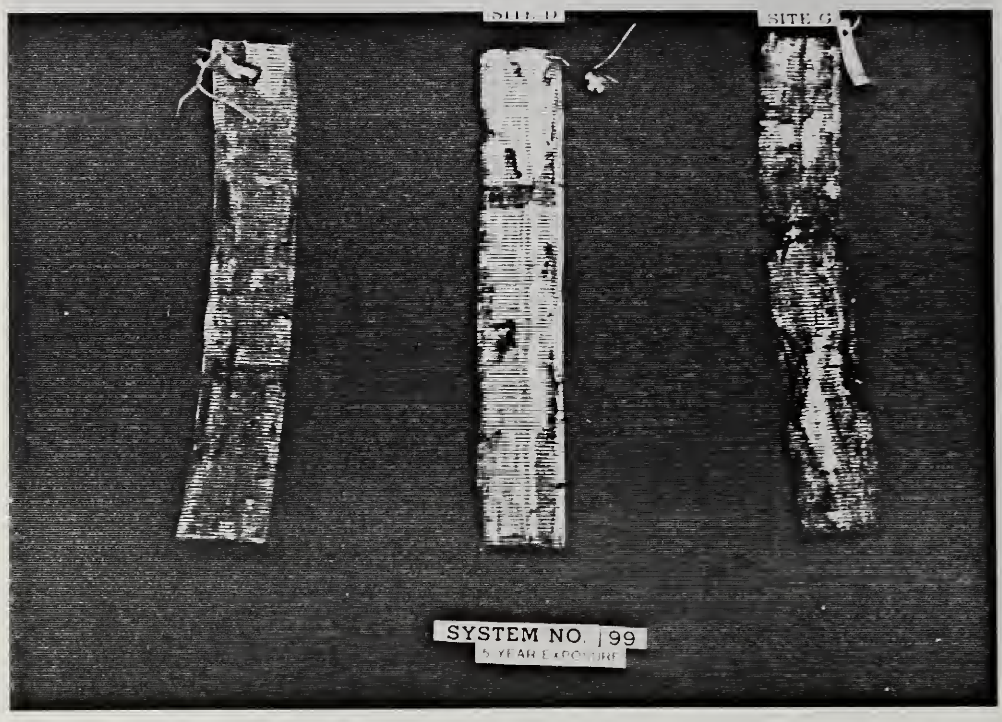

Figure 10. Outer Shield: System 99, Sites B, D, and G, left to right, exposed for five years. Dark areas indicate corrosion at the window and ring areas on the specimens from Sites D and G, with severe corrosion on the specimen from Site G.

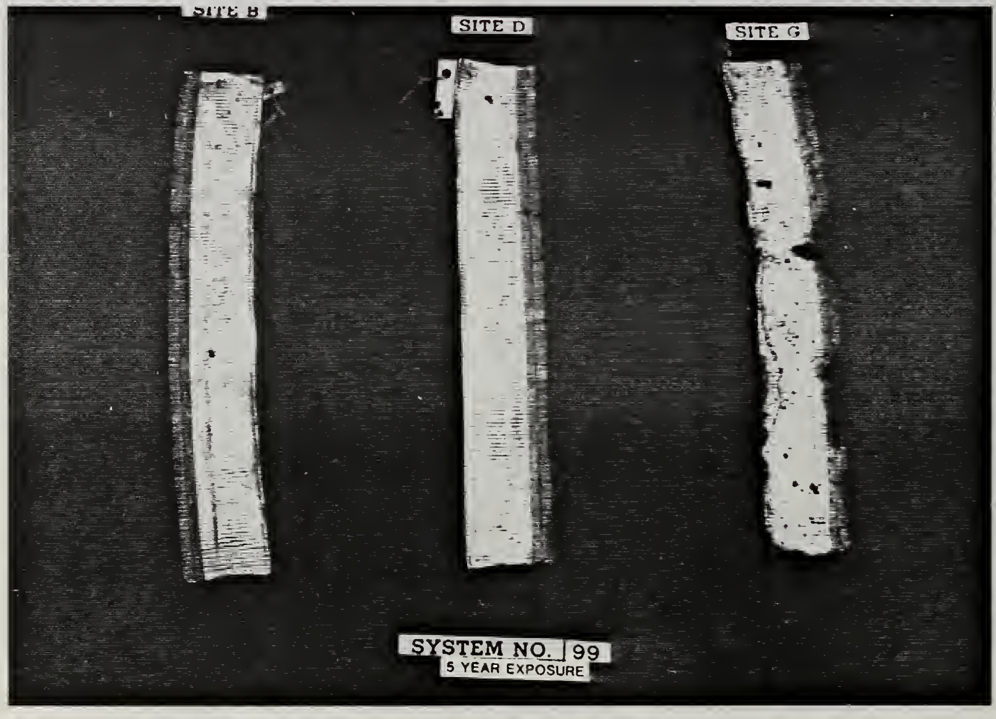

Figure 11. Inner shield: System 99, Sites B, D, and G, left to right, exposed for the five years. Dark areas indicate corrosion at all areas on the specimen from site G.

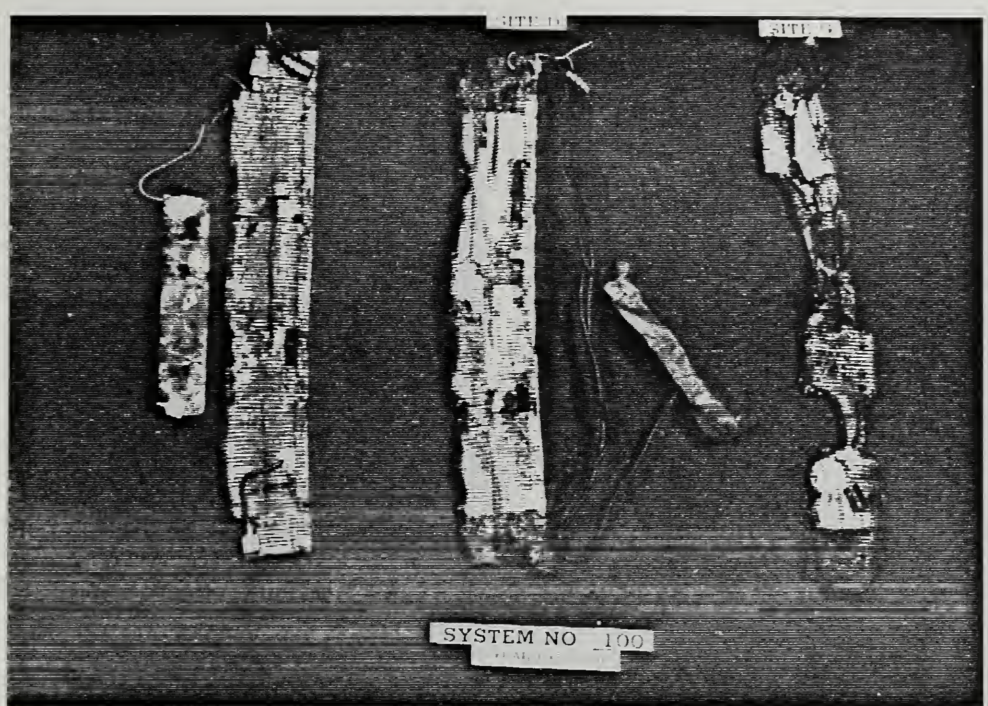

Figure 12. Outer Shield: System 100, Sites B, D, and G, left to right, exposed for five years. Coupling this system to copper accelerated corrosion on specimens at window and ring areas, with severe corrosion at all areas on the specimen from Site G.

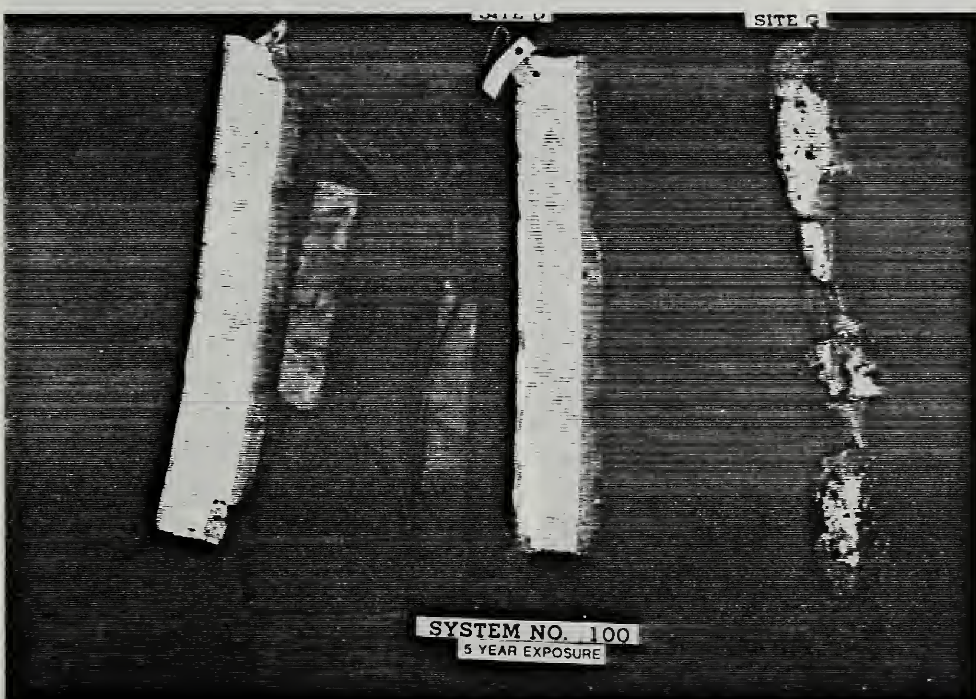

Figure 13. Inner Shield: System 100, Sites B, D, and G, left to right, exposed for five years. Coupling this system to copper accelerated degradation at the window and ring areas, with severe degradation on the specimen from Site G.

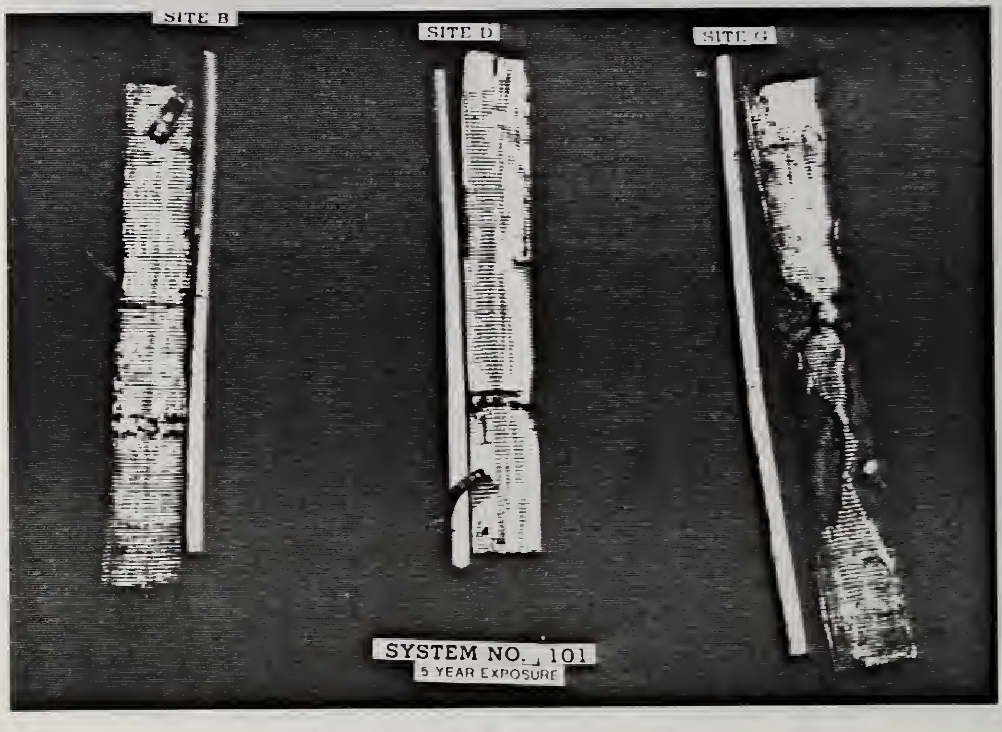

Figure 14. Outer Shield: System 101, Sites B, D, and G, left to right, exposed for five years. Dark areas indicate corrosion at window and ring areas, with severe corrosion on the specimen from Site G.

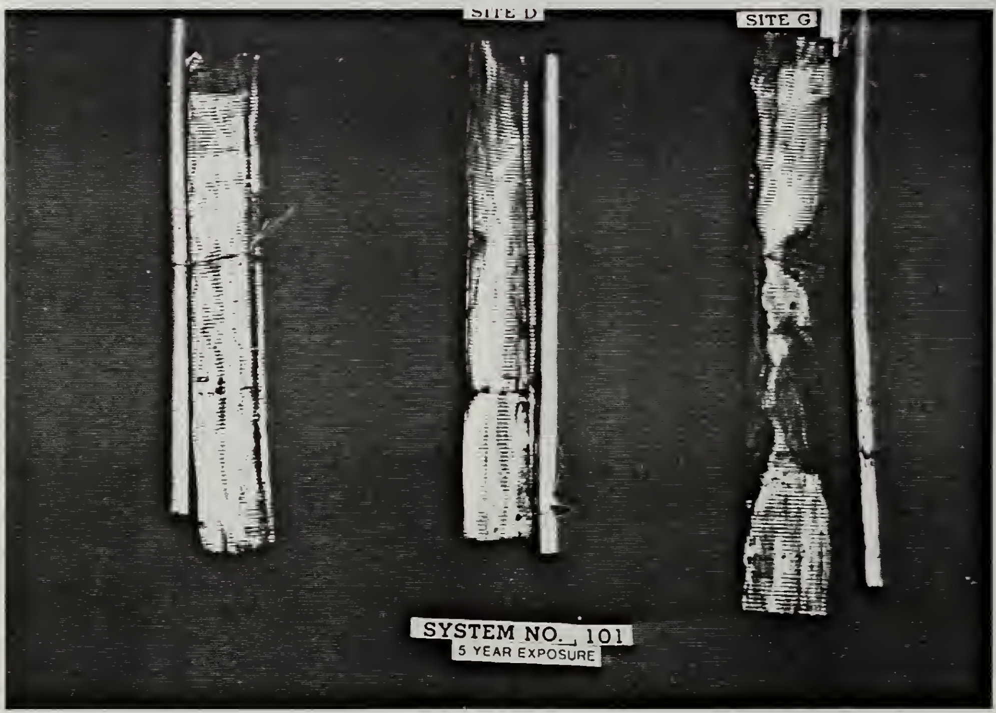

Figure 15. Inner Shield: System 101, Sites B, D, and G, left to right, exposed for five years. Dark areas indicate severe corrosion at the window and ring areas on the specimen from Site G.

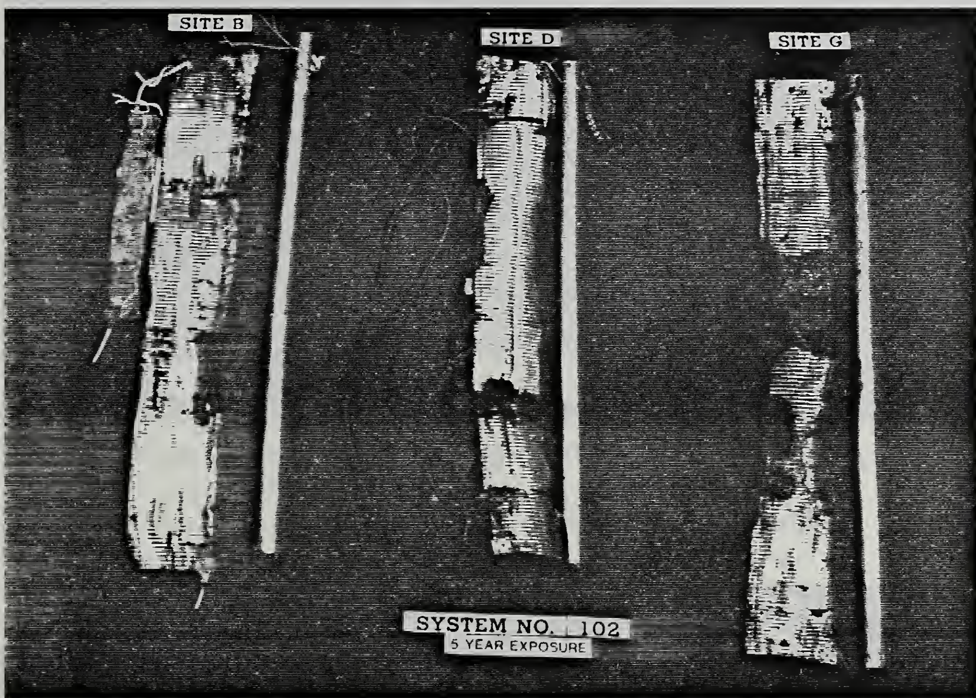

Figure 16. Outer Shield: System 102, Sites B, D, and G left to right, exposed for five years. Coupling this system to copper severely accelerated corrosion on specimens from all sites.

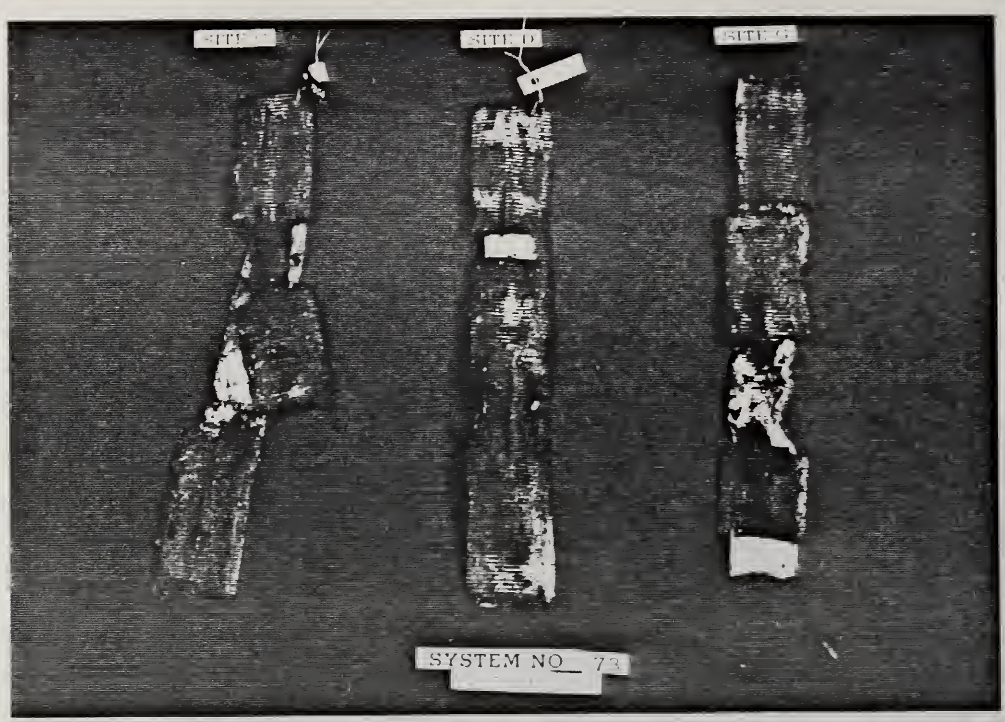

Figure 17. Outer Shield: System 73, Sites C, D, and G, left to right, exposed for seven years. Severe corrosion at the window and ring areas on specimens from Sites C and D, with severe corrosion at all areas on the specimen from Site G.

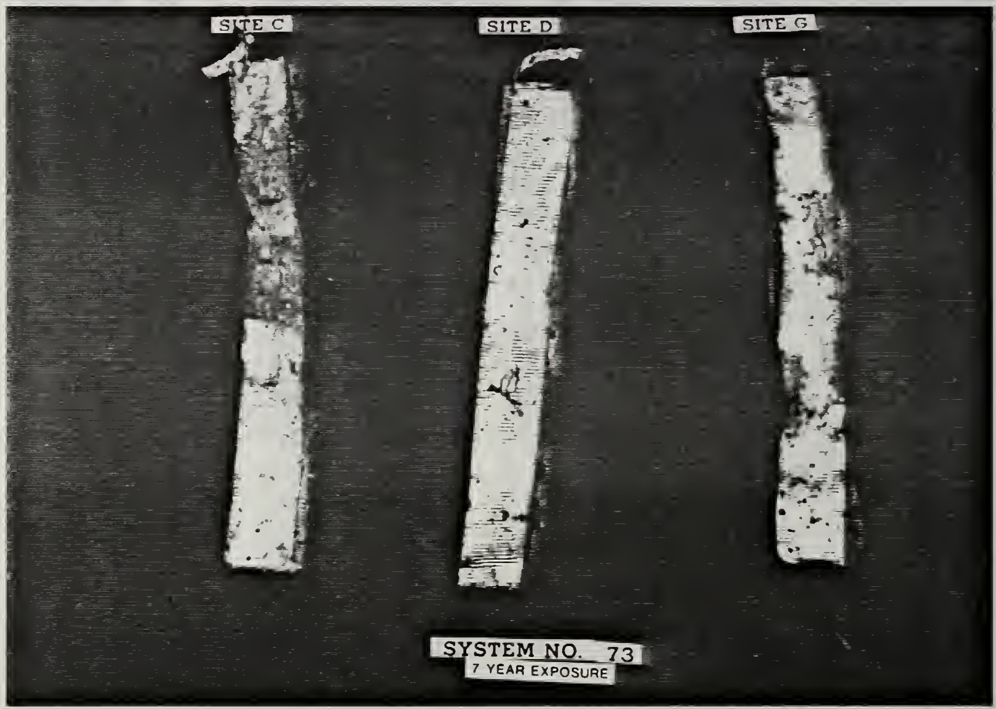

Figure 18. Inner Shield: System 73, Sites C, D, and G left to right, exposed for seven years. Severe degradation at all areas on specimens from Sites C and G, except at the under jacket area on the specimen from Site G, which remained excellent.

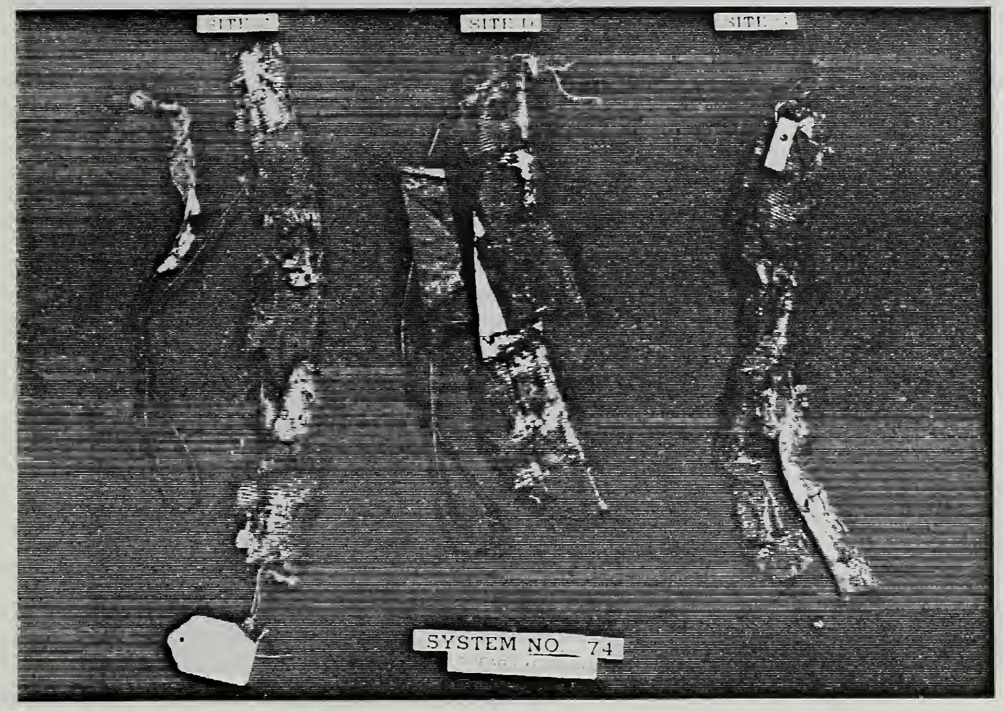

Figure 19. Outer Shield: System 74, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated corrosion severely on specimens from all sites.

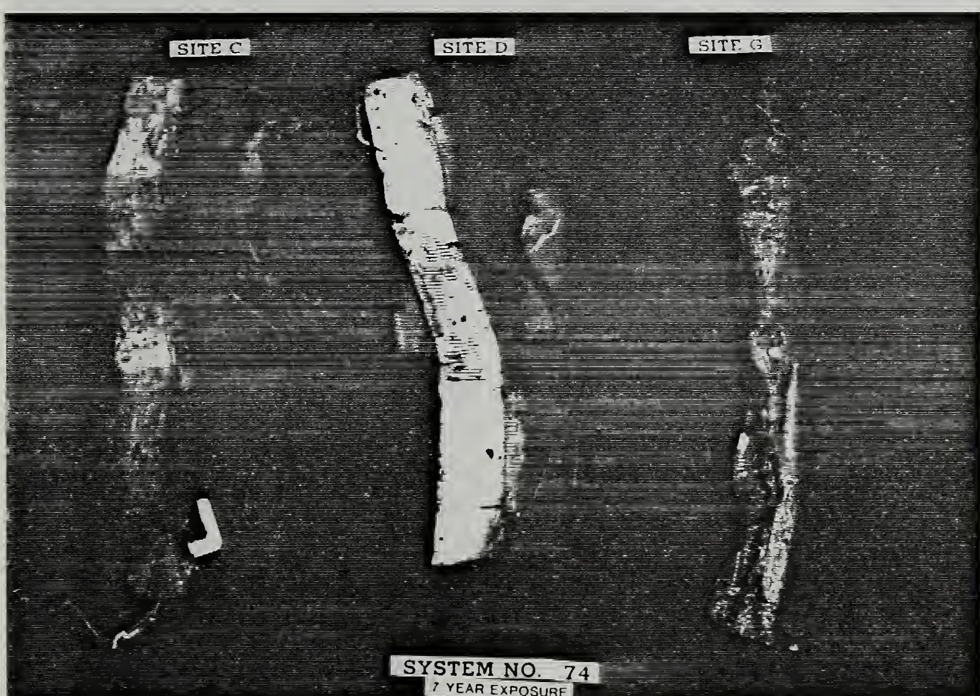

Figure 20. Inner Shield: System 74, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated corrosion on specimens from all sites.

Figure 21. Outer Shield: System 75, Sites C, D, and G, left to right, exposed for seven years. Dark areas indicate severe corrosion at all areas on the specimen from Site G.

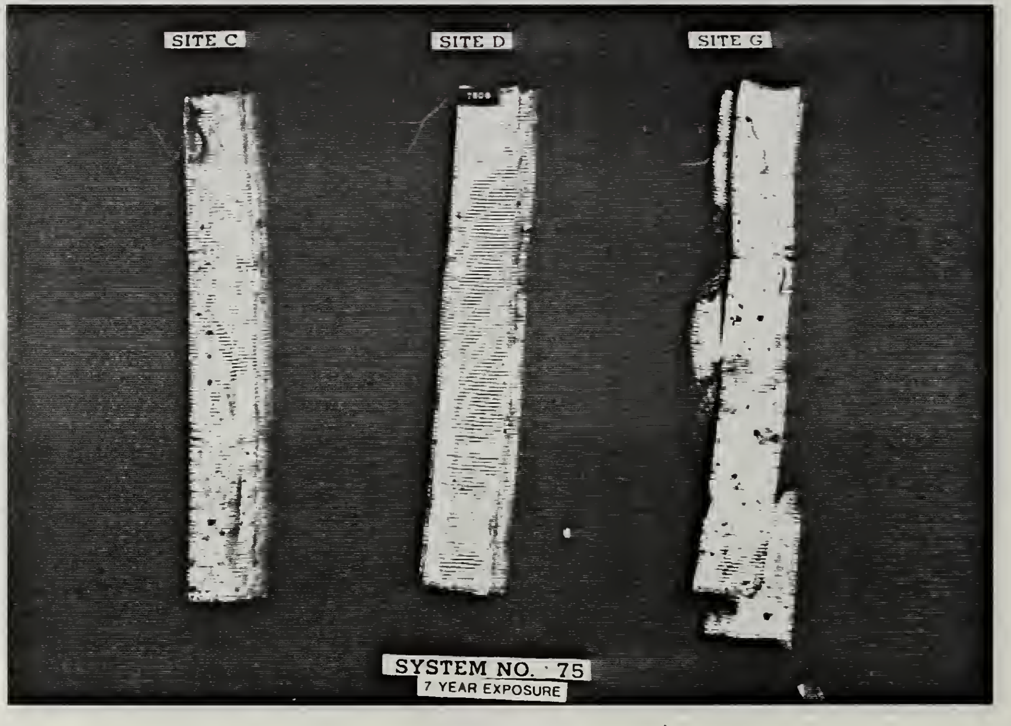

Figure 22. Inner Shield: System 75, Sites C, D, and G, left to right, exposed for seven years. Degradation of the window area on the specimen from Site G.

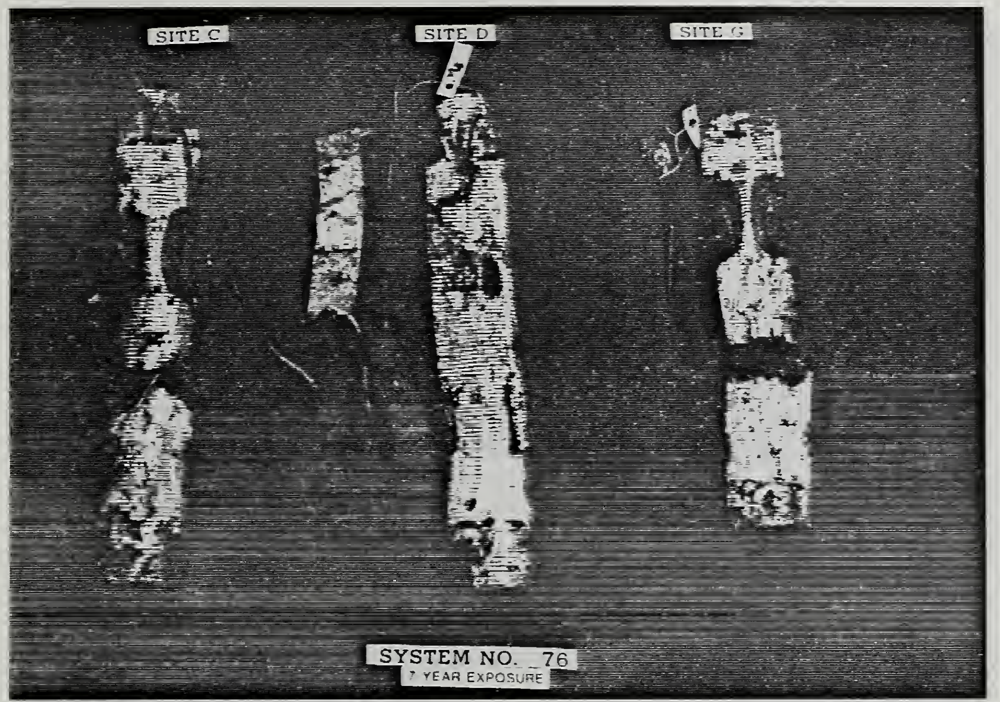

Figure 23. Outer Shield: System 76, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated corrosion. Dark areas indicate severe corrosion at all areas except under jacket areas on specimens from Sites C and G.

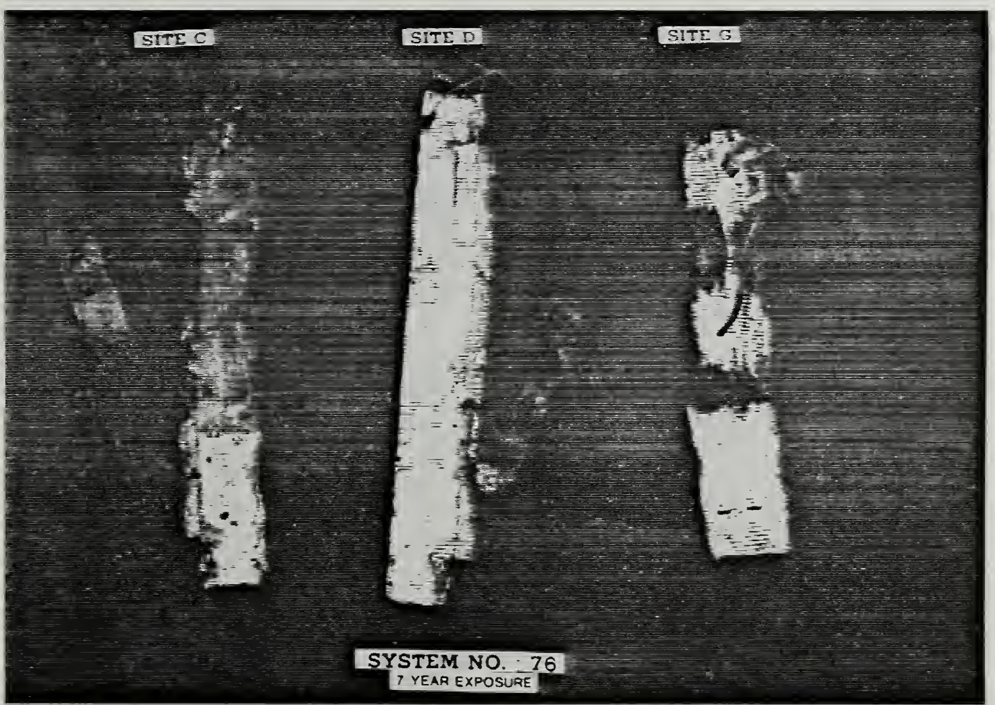

Figure 24. Inner Shield: System 76, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated degradation at all areas on the specimens from Sites C and G.

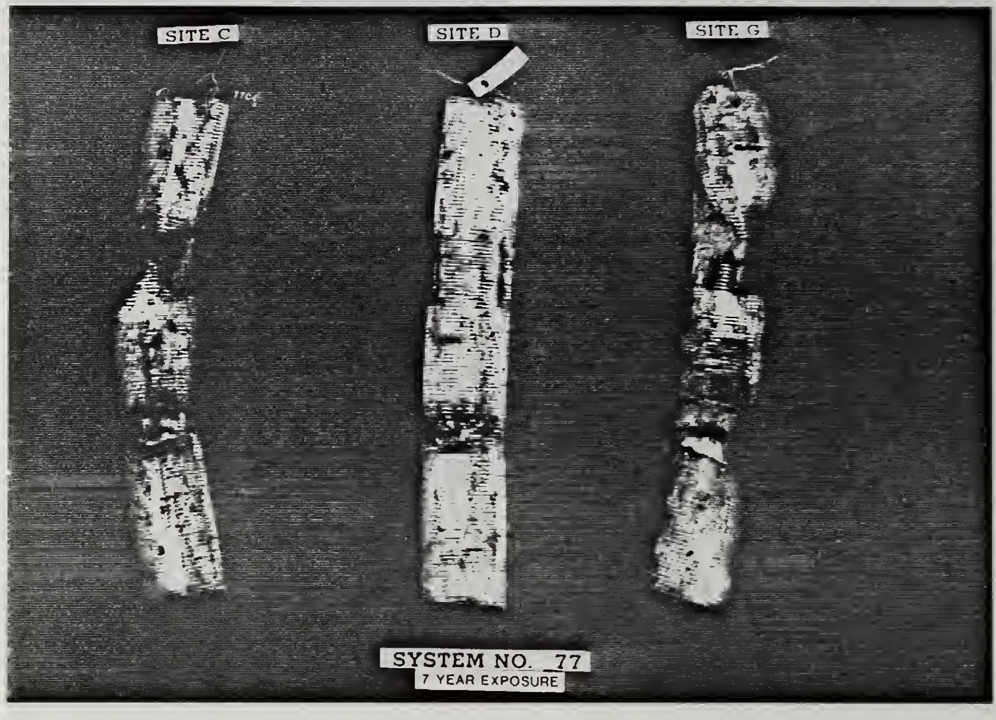

Figure 25. Outer Shield: System 77, Sites C, D, and G, left to right, exposed for seven years. Dark areas indicate severe corrosion at all areas, except under jacket areas on specimens from Sites C and G.

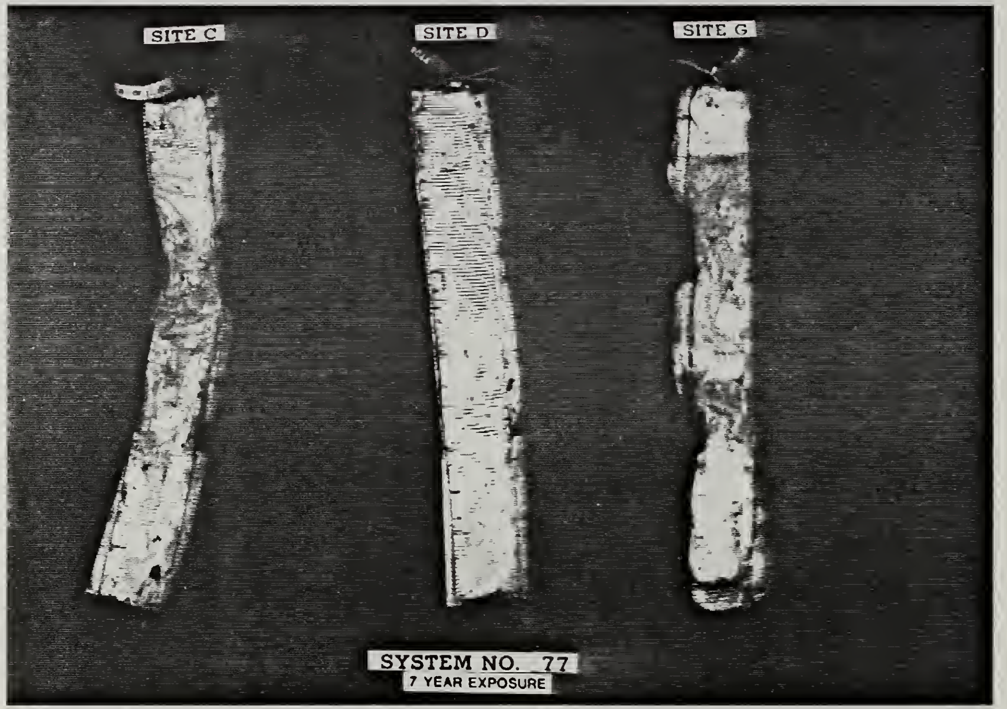

Figure 26. Inner Shield: System 77, Sites C, D, and G, left to right, exposed for seven years. Darker areas indicate severe degradation at all areas on specimens from Site C and G.

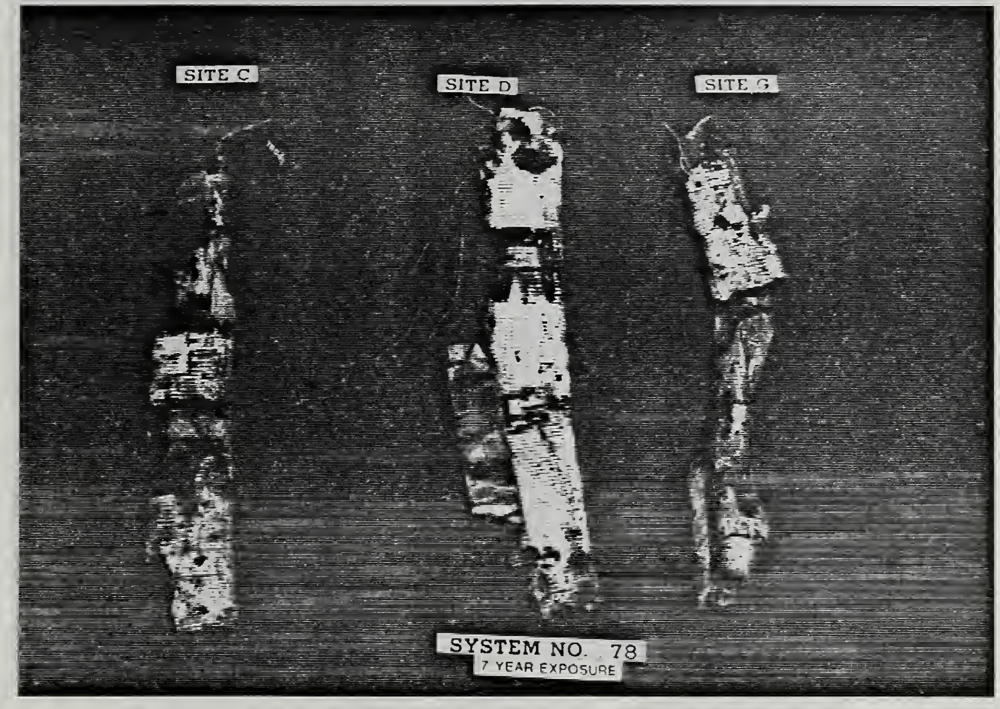

Figure 27. Outer Shield: System 78, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated corrosion severely on specimens from all sites.

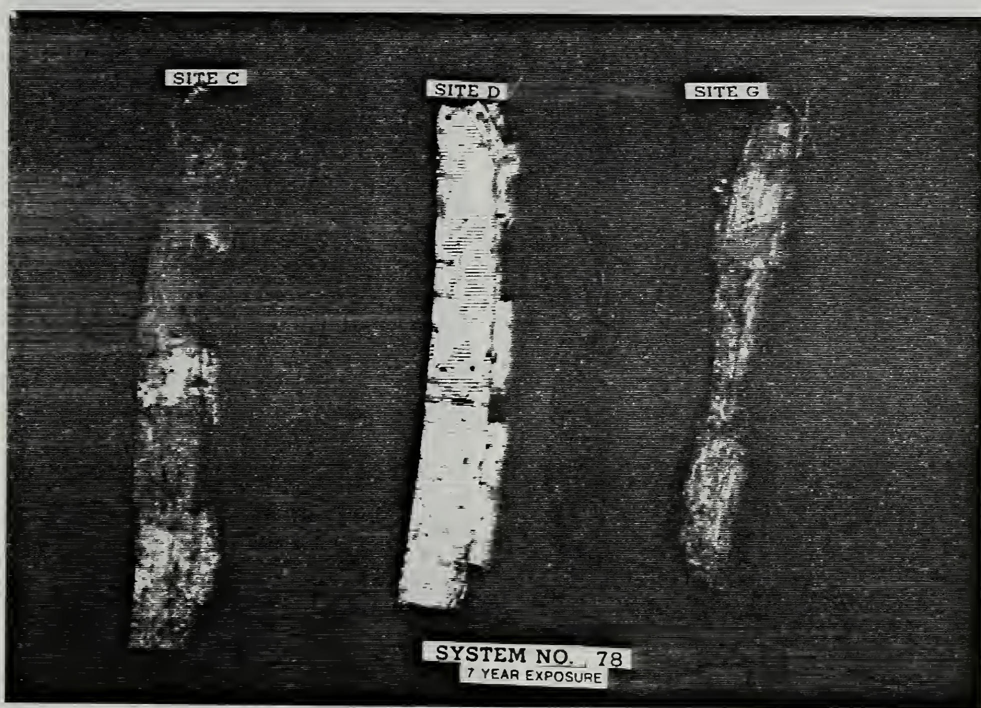

Figure 28. Inner Shield: System 78, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated degradation severely at all areas on specimens from all sites.

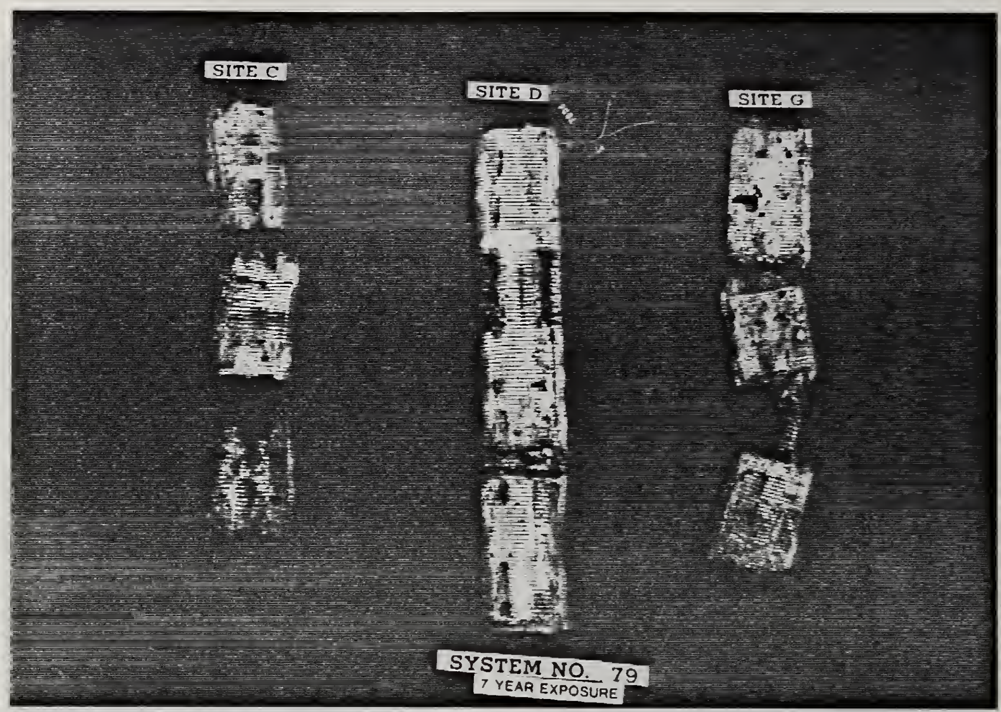

Figure 29. Outer Shield: System 79, Sites C, D, and G, left to right, exposed for seven years. Severe corrosion at all areas on the specimens from Sites C and G.

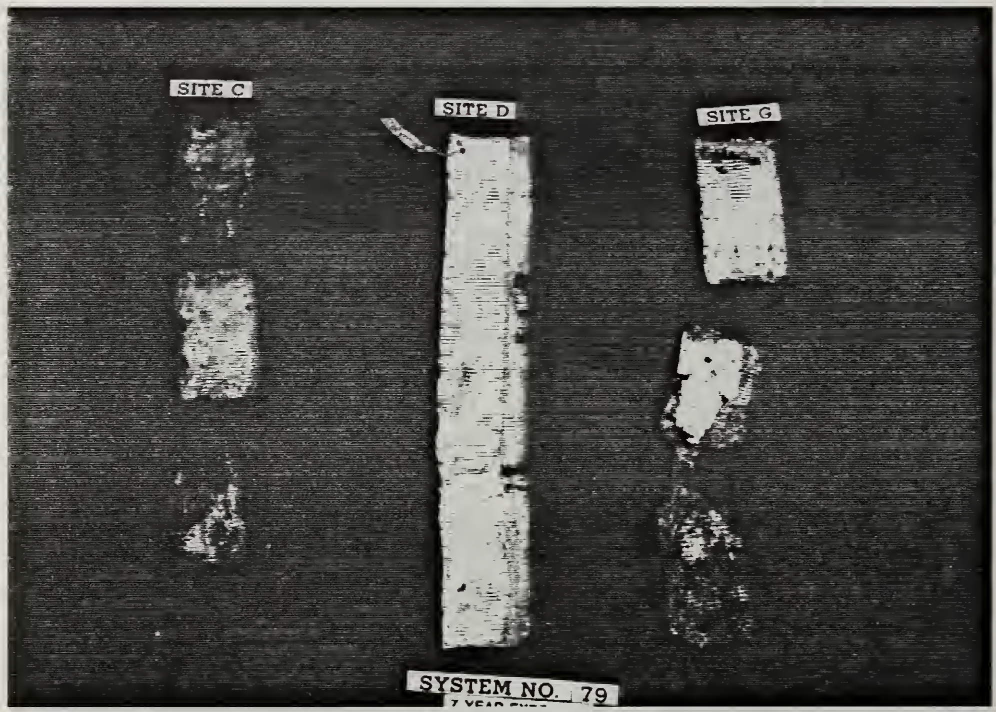

Figure 30. Inner Shield: System 79, Sites C, D, and G, left to right, exposed for seven years. Severe degradation at all areas on specimens from Sites C and G.

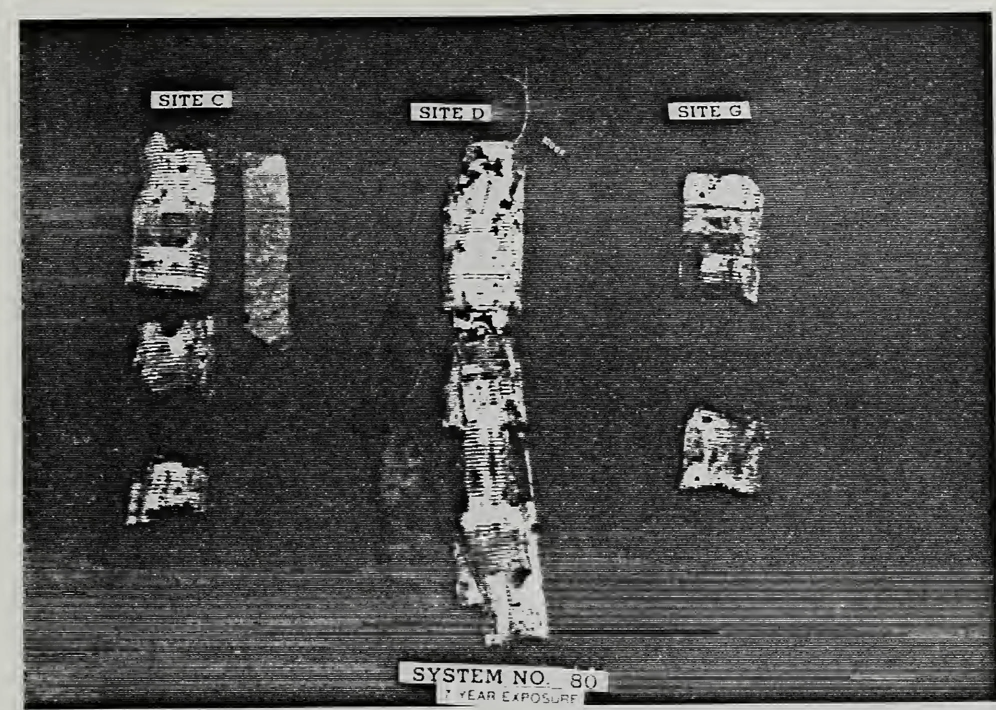

Figure 31. Outer Shield: System 80, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated corrosion at all sites.

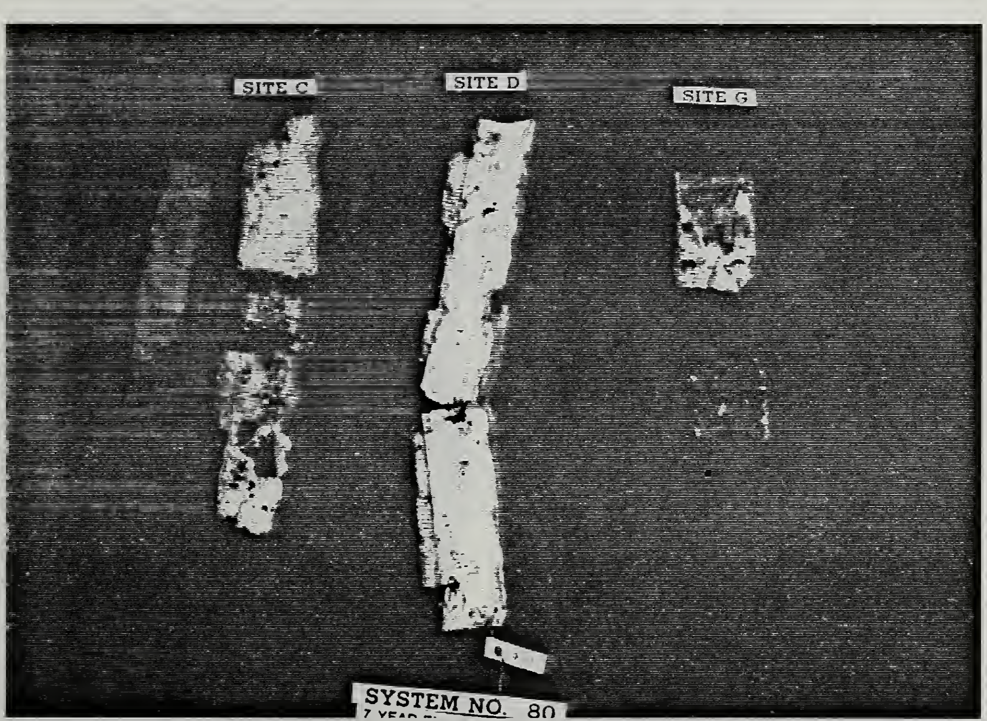

Figure 32. Inner Shield: System 80, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated corrosion at all sites.

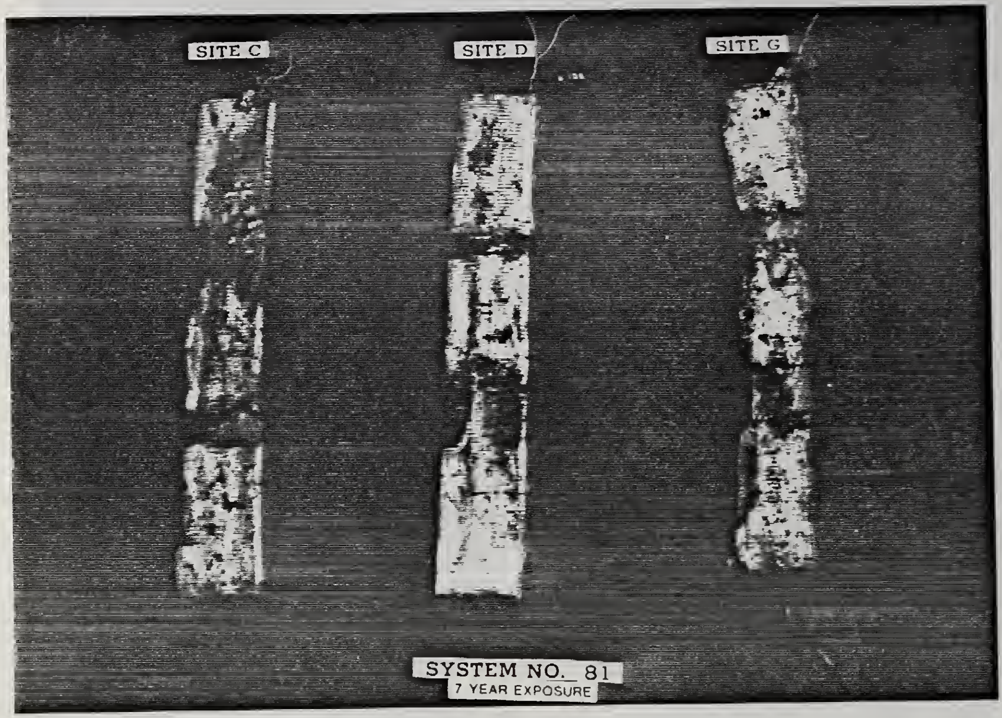

Figure 33. Outer Shield: System 81, Sites C, D, and G, left to right, exposed for seven years. Dark areas indicate severe corrosion at all areas on specimens from Sites C and G.

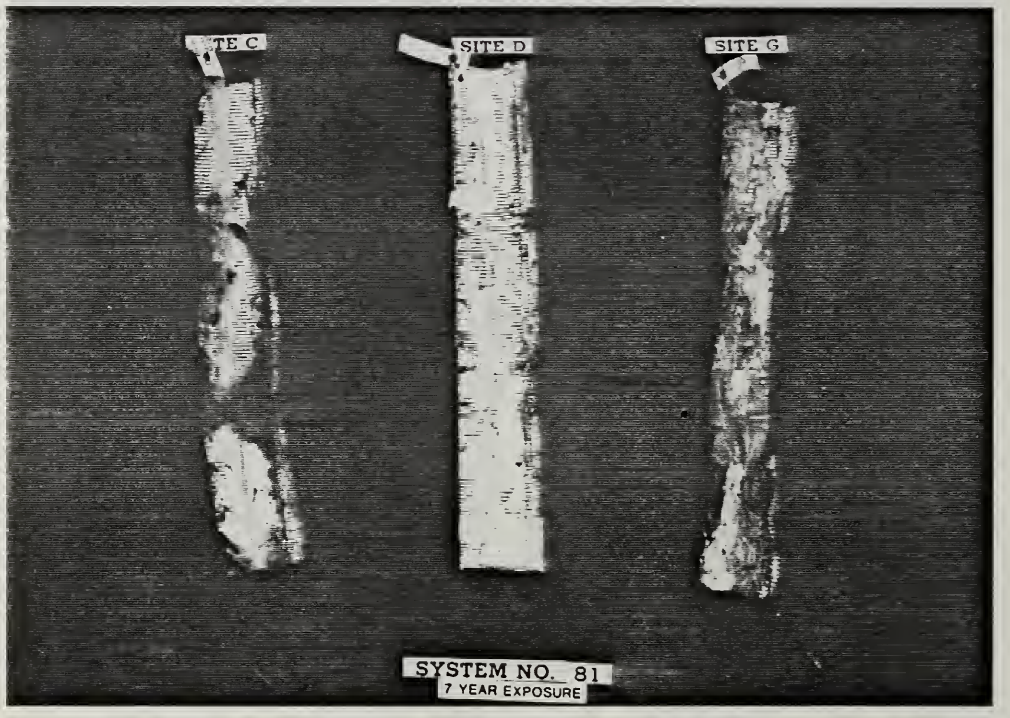

Figure 34. Inner Shield: System 81, Sites C, D, and G, left to right, exposed for seven years. Severe degradation at the window and ring areas on the specimen from Site C, with severe degradation at all areas on the specimen from Site G.

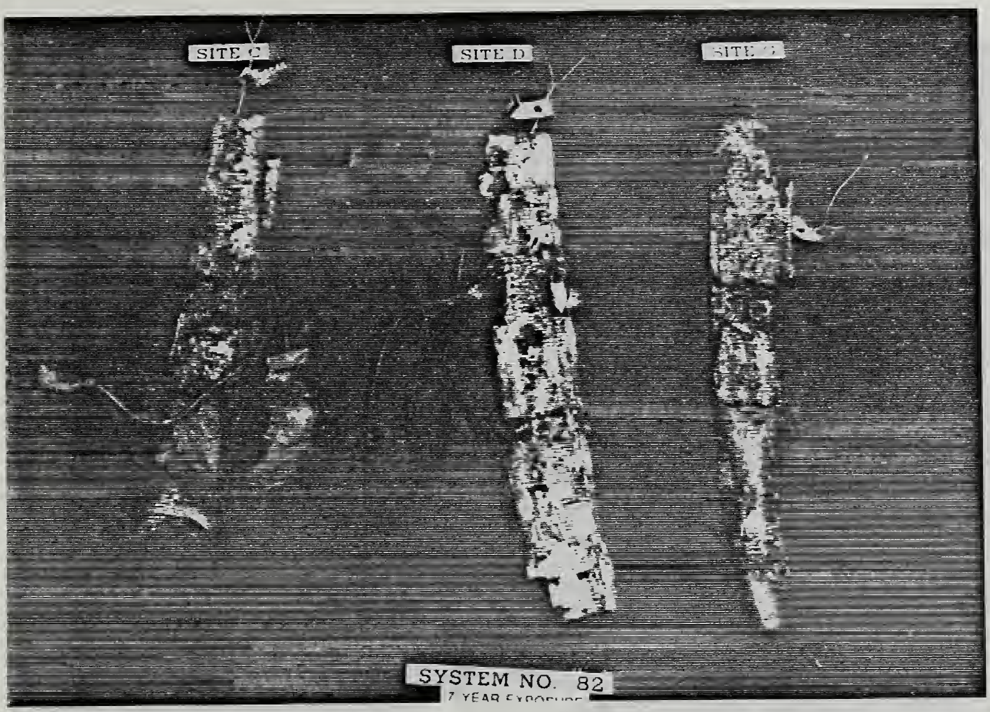

Figure 35. Outer Shield: System 82, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated corrosion severely at all areas on all specimens.

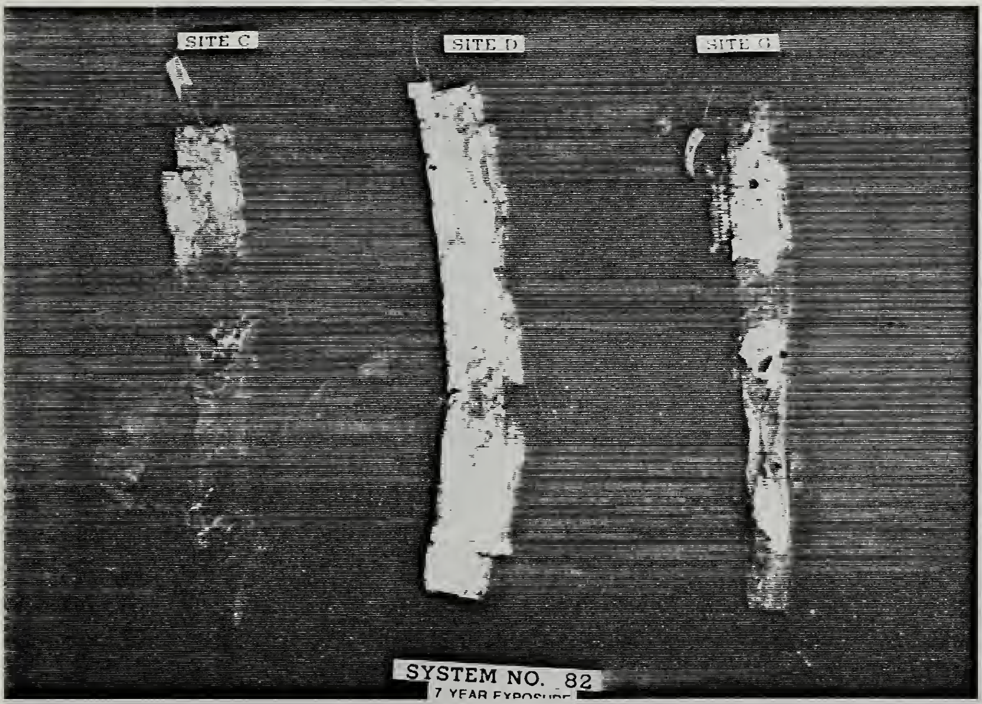

Figure 36. Inner Shield: System 82, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated degradation severely at all areas on all specimens.

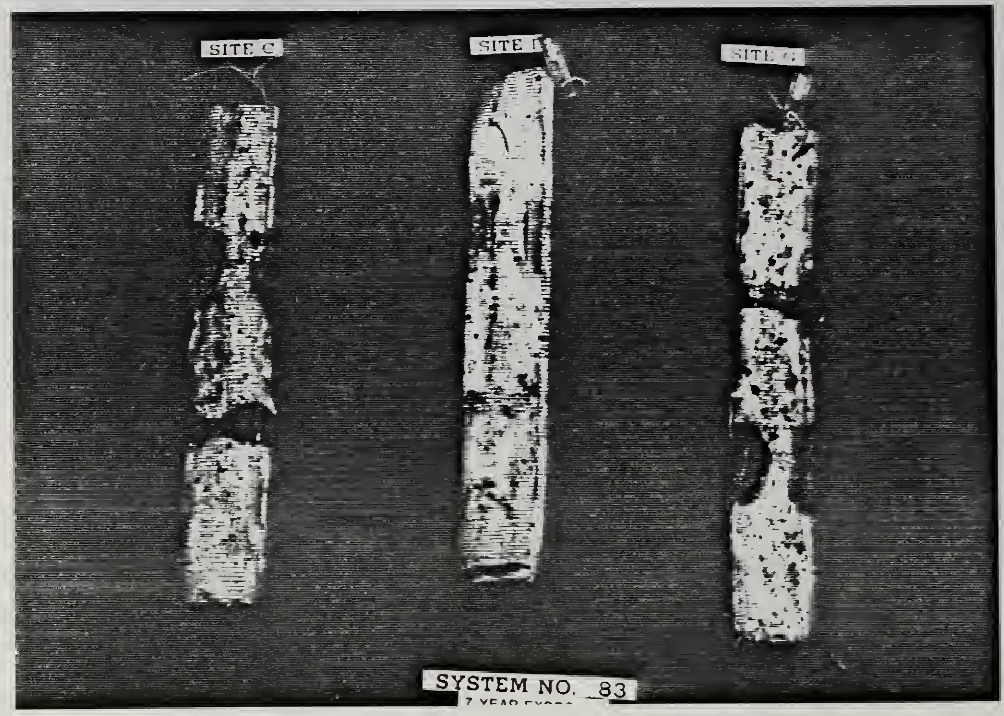

Figure 37. Outer Shield: System 83, Sites C, D, and G, left to right, exposed for seven years. Dark areas indicate corrosion with severe corrosion at the window and ring areas on the specimens from Sites C and G.

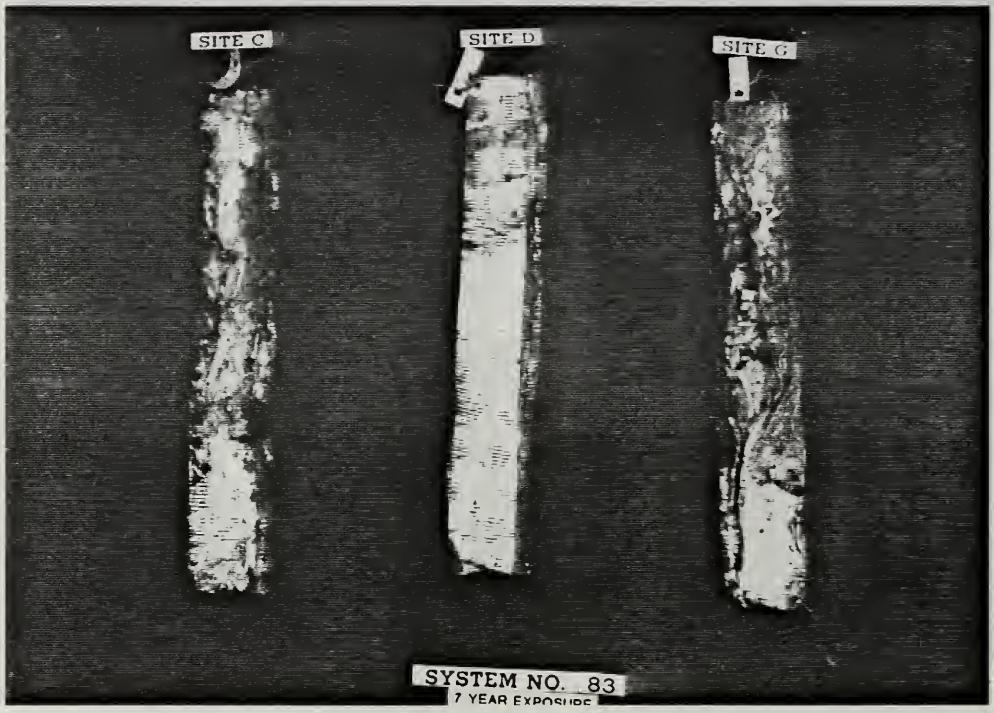

Figure 38. Inner Shield: System 83, Sites C, D, and G, left to right, exposed for seven years. Severe degradation at all areas on specimens from Sites C and G.

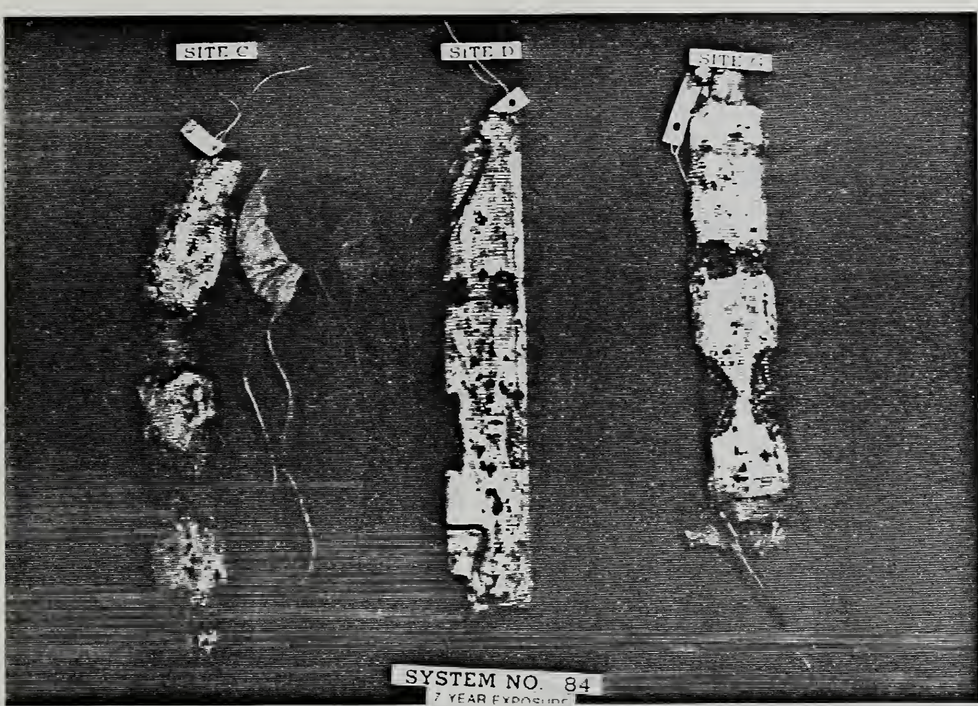

Figure 39. Outer Shield: System 84, Sites C, D, and G, left to right, exposed for seven years. Severe corrosion at the window and ring areas on the specimen from Site D, with severe corrosion at all areas on the specimens from Sites C and G.

Figure 40. Inner Shield: System 84, Sites C, D, and G, left to right, exposed for seven years. Severe degradation at all areas on specimens from Sites C and G.

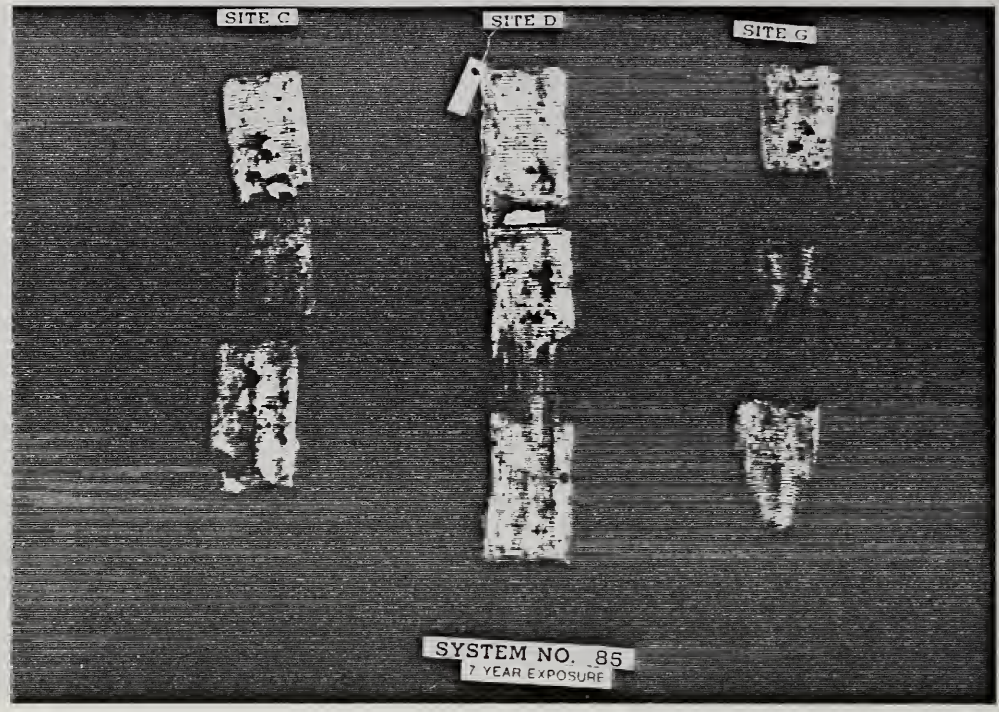

Figure 41. Outer Shield: System 85, Sites C, D, and G, left to right, exposed for seven years. Severe corrosion at the window and ring areas on the specimen from Site G, with severe corrosion at all areas on the specimens from Sites C and G.

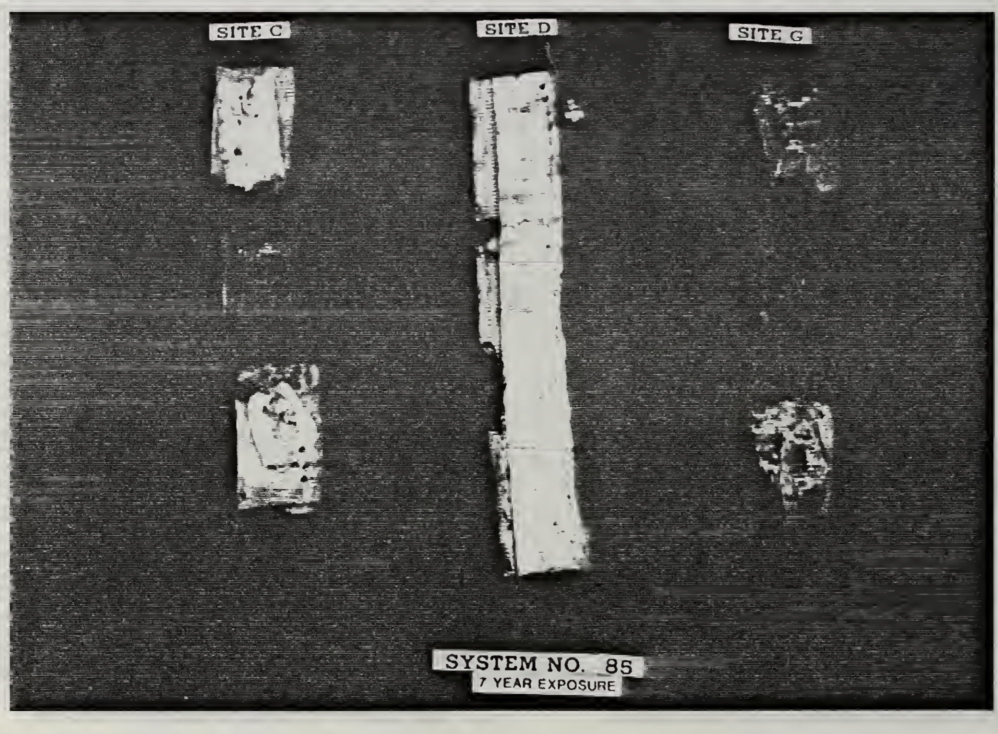

Figure 42. Inner Shield: System 85, Sites C, D, and G, left to right, exposed for seven years. Severe degradation at all areas on specimens from Sites C and G.

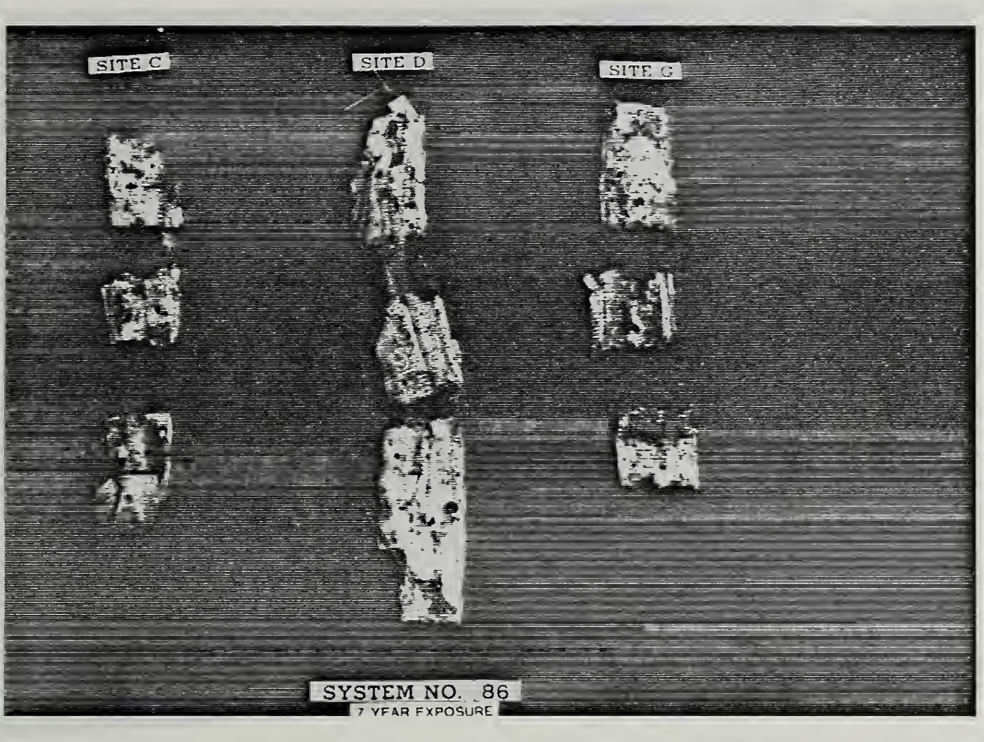

Figure 43. Outer Shield: System 86, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated corrosion severely at all areas on all specimens.

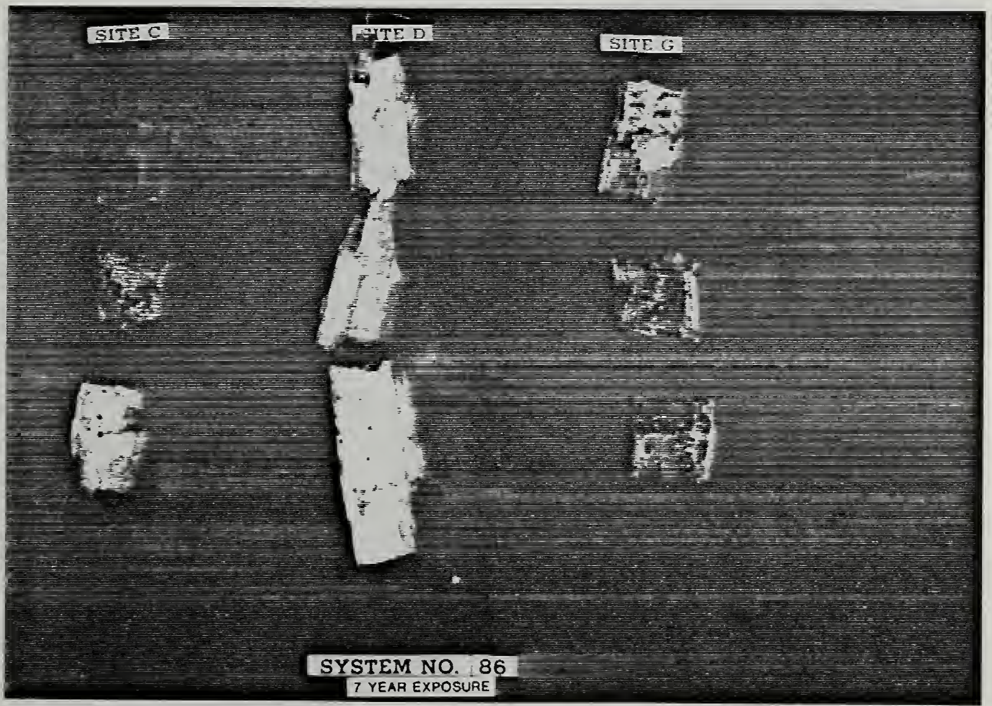

Figure 44. Inner Shield: System 86, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated corrosion severely at all areas on all specimens.

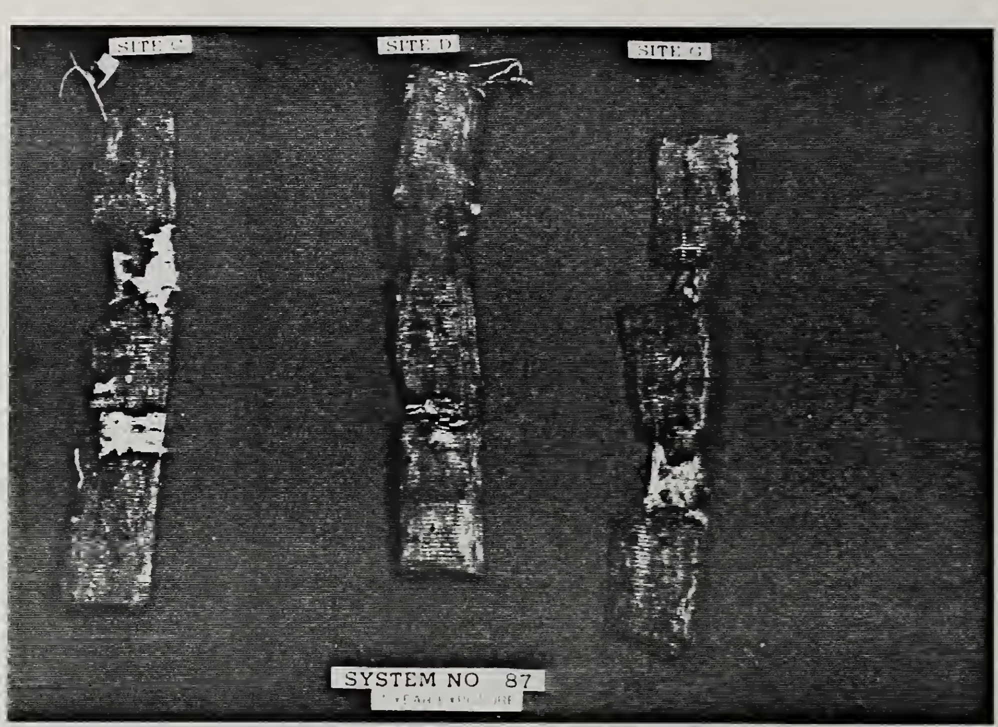

Figure 45. Outer Shield: System 87, Sites C, D, and G, left to right, exposed for seven years. Severe corrosion at the window and ring areas on the specimen from Site D, with severe corrosion at all areas on specimens from Sites C and G.

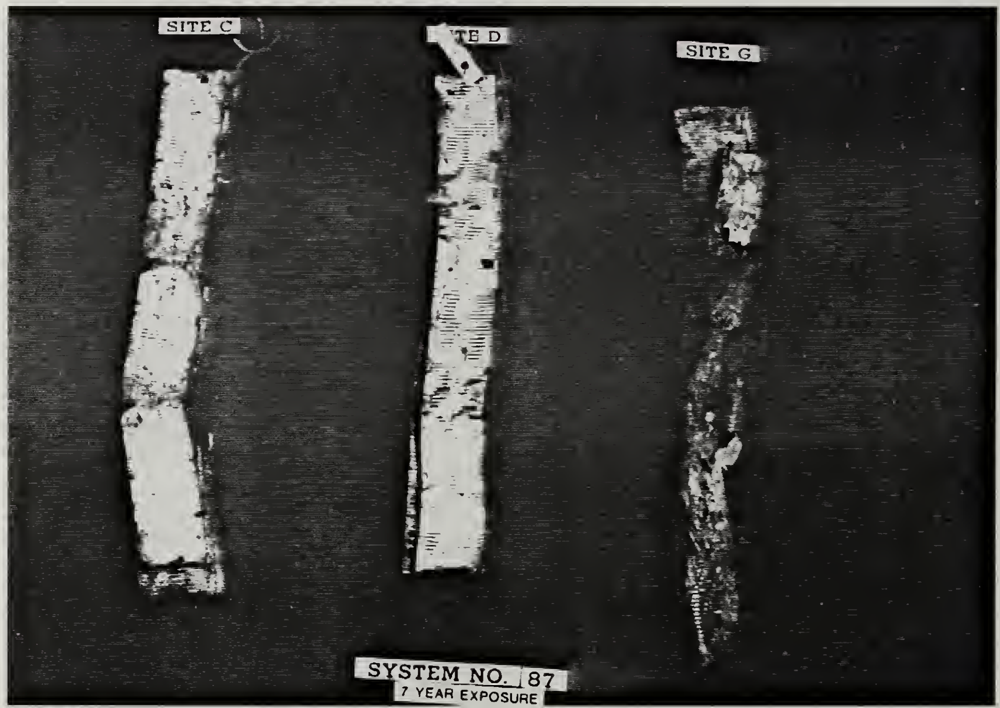

Figure 46. Inner Shield: System 87, Sites C, D, and G, left to right, exposed for seven years. Severe degradation at all areas on specimens from Sites C and G, except under jacket areas on the specimen from Site C.

Figure 47. Outer Shield: System 88, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated corrosion severely at all areas on all specimens.

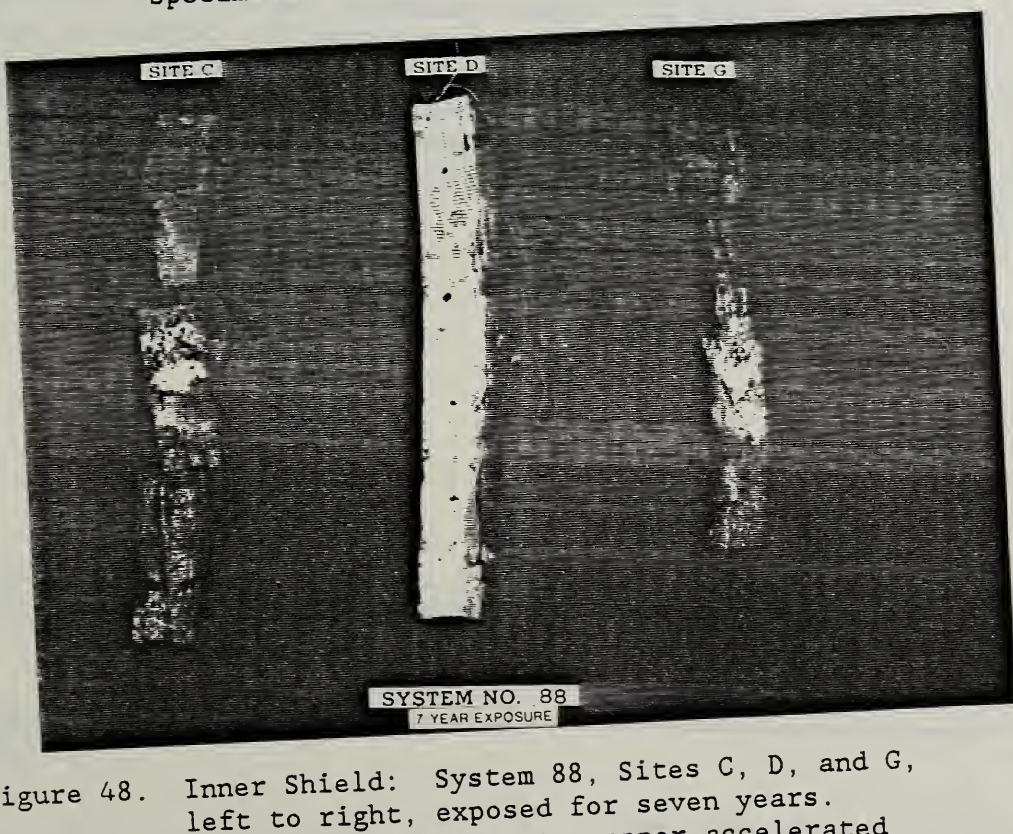

Figure 48. Inner Shield: System 88, Sites C, D, and G, left to right, exposed for seven years. Coupling this system to copper accelerated degradation severely at all areas on all specimens.

NBS-114A (REV. 2-80)

U.S. DEPT. OF COMM. **BIBLIOGRAPHIC DATA SHEET** *(See instructions)*	1. PUBLICATION OR REPORT NO. NBSIR 87-3546	2. Performing Organ. Report No.	3. Publication Date

4. TITLE AND SUBTITLE

Corrosion Evaluation of Underground Telephone Cable Shielding Materials

5. AUTHOR(S)

J. L. Fink, D. Mathews, G. Hessler, E. Speed

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

8. Type of Report & Period Covered

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

Rural Electrification Administration
Department of Agriculture
Washington, DC 20250

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

Corrosion data are given on the performance of base and plastic-coated metals intended for use as cable shields for buried telephone cable. The materials investigated on specially prepared specimens were buried for periods up to seven years in six different soil environments. Metals tested included homogeneous plastic-bonded and metallurgically bonded laminates. Some specimens were exposed bare (uncoated), while others had plastic coatings or other types of coatings on either one or both sides. Metals studied included aluminum, copper, low carbon steel, and stainless steel alloys.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

alloys; corrosion; metallurgically-bonded; metals; plastic-bonded; soils; telephone cables; underground.

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14. NO. OF PRINTED PAGES

113

15. Price

$18.95

USCOMM-DC 6043-P80